



10th May, 1913.

Dear Sir,

I send you herewith the Thesis which you have kindly agreed to examine in conjunction with Professor Geikie. When you have read it, be good enough to send it, with a note of your opinion as to its merits, to the Professor, with a view to the presentation of a joint report to the Faculty of Science. Kindly acknowledge receipt.

I am,

Yours truly,

Dr Horne.

551 (4125)

Aberdeen Natural History and Antiquarian Society

SURVEY OF THE NATURAL HISTORY AND ANTIQUITIES OF THE
VALLEY OF THE DEE

VOL. I. PART 2

THE PHYSICAL GEOLOGY OF THE DEE VALLEY

I hereby declare that this paper, which is submitted along with "The Physical Geology of the Don Valley" (in ms.) as a Thesis for the Degree of Doctor of Science, is a record of original research undertaken by me; that the work done and results recorded, except where acknowledgment is made, are entirely my own; and that the Thesis has been composed by myself.

21st, April, 1913.



THE PHYSICAL GEOLOGY
OF
THE DEE VALLEY.

BY
ALEXANDER BREMNER, M.A., B.Sc.

ABERDEEN
THE UNIVERSITY PRESS
1912

MANY of the lectures given during the winter meetings of the Aberdeen Natural History and Antiquarian Society have embodied valuable contributions to a fuller knowledge of the Natural History and Antiquities of the adjoining districts, and it has been an ambition of the Society to publish these contributions as soon as financial circumstances would permit.

With a view to utilising to some extent the information already acquired, and to encourage further investigations by local workers, the Society has promoted a scheme for a Survey of the Natural History and Antiquities of the Valley of the Dee, and has been fortunate in securing the co-operation of many willing helpers. It is anticipated that the completed work will occupy four volumes, dealing respectively with the Geology, Zoology, Botany and Antiquities of the area included within the watershed of the Valley of the Dee. Each of these volumes when complete will include a number of parts dealing with different branches of the subject, and it has been arranged that these should first of all appear separately so as to prevent the delay in publication that otherwise would be unavoidable. Mr. Bremner's valuable paper on the Physical Geology of the Valley of the Dee, the result of years of patient investigation in the field, is the first contribution towards this Survey, and is issued as Part 2 of Volume I.

ROBERT M. CLARK,

Hon. Secretary.

UNIVERSITY OF ABERDEEN,

May, 1912.

CONTENTS

CHAP.	PAGE
I. THE PROBABLE AGE AND ORIGIN OF THE DEE VALLEY	1
II. GRADIENT OF THE RIVER BED	8
III. CAPTURE OF THE HEAD-WATERS OF THE RIVER BY TRIBUTARIES OF THE SPEY AND TAY	12
IV. RELATION BETWEEN THE COURSE OF THE RIVER AND ITS TRIBUTARIES AND GEOLOGICAL STRUCTURE	19
V. EFFECTS OF ICE ON THE PHYSICAL FEATURES OF THE VALLEY	20
1. ICE-ABRASION	22
2. ICE-EROSION	24
3. BOULDER-CLAY	31
4. MORAINES	37
5. KAMES	45
6. OVERFLOW CHANNELS AND GLACIAL LAKES	46
VI. SPECIAL POINTS REGARDING TRIBUTARIES	67
VII. RIVER TERRACES	70
VIII. SCENIC EFFECTS DUE TO THE NATURE OF THE ROCKS	72
APPENDIX	83
BIBLIOGRAPHY	85
INDEX OF LOCALITIES	87

THE PHYSICAL GEOLOGY OF THE DEE VALLEY.

THE history and antiquities, the fauna and flora of Deeside, have received fairly adequate attention : its solid geology has been mapped.¹ But little notice has been taken of its physical features except in their æsthetic aspect. This paper is an attempt to deal with some of the more notable of these features from a strictly scientific standpoint.

I. THE PROBABLE AGE AND ORIGIN OF THE DEE VALLEY.

At the outset it requires to be stated that anything that may be said regarding the age and origin of the Dee Valley must be looked upon as to a large extent mere speculation. Hypotheses may be stated, however, that have more or less evidence in their favour.

In order to make clear one view that may be propounded as to the age and origin of the Dee and its valley, it is necessary to sketch in outline the geological history of the Central Highlands, that is, of Scotland between the Great Glen and the boundary fault of the Highlands running from the Clyde to Stonehaven.

¹ Geological Survey Map of Scotland, Sheets 65, 66, 67, 75, 76, 77, of 1-inch Map. Sheet 64 is not yet published. Memoirs have been issued in explanation of Sheets 75 and 76.

The rocks of this region are metamorphosed sedimentary rocks and intrusive igneous rocks. The sedimentary rocks may be of very different ages, but all are so highly crystalline that no fossil evidence of their age has been or is likely to be obtained. The presence of persistent bands of limestone, of graphitic schists, and of pebbly quartzites clearly indicates sedimentary origin.

The bed of the primeval ocean in which they were laid down was upheaved: the calcareous materials, muds, and sands of its bottom were folded, compressed, contorted, sheared, and probably pushed over each other till they became converted into what we now call "Highland Schists". Already intruded amongst them or injected during the folding were various igneous rocks, both acid and basic. These shared in, and perhaps by their high temperature contributed to, the metamorphism of the sedimentary strata.

So much altered are the Highland schists from their original condition, so much affected have they been by earth-movements, that it is little to be wondered at that conflicting views have been entertained regarding the order of succession among them,¹ or that even to attempt the correlation of rocks north and south of the granitic axis of the Eastern Grampians is hazardous.

The first or schistosity movements to which the Central Highland area was subjected, probably resulted in the production of one or more ridges or axes of upheaval running approximately north-east and south-west, *i.e.*, in the direction of the prevalent strike of the schists as we now know them.

Thus the Highland hills began their history as mountains of elevation like the Alps and Himalayas in later times. But denudation operated upon them in the usual way. Attacked by frost, rain, and running water, the ridges were gradually worn away. Rivers established for themselves an orderly system of valleys, transverse or longitudinal. Capture of one stream by another took place, and the

¹ *Summary of Progress of the Geolog. Survey*, 1898, p. 21; 1899, p. 30. *Quarterly Journ. of Geolog. Soc.*, vol. lx., pp. 400-49.

valley of the composite river was partly longitudinal, partly transverse.¹

Since the dominant ridges followed the strike of the schists, the river valleys ran either north-west and south-east (transverse) or north-east and south-west (longitudinal). An examination of any good physical map of the Central Highlands will show that those are still the directions of the vast majority of the valleys. Of those that deviate from the normal direction, the valley of the Dee is by far the most important. It is neither transverse nor longitudinal, and for this there must be a reason (Map 1).

That since the schistosity movements there have been disturbances of great magnitude (apart from normal faulting) is clear from the deviation of the bands of schist from their usual strike in different parts of the area. As the schists of the Banffshire Hills approach the northern boundary of the Cairngorm granite, their strike changes from north-east and south-west to north-west and south-east; the schists and gneissose rocks of the Dee Valley below Dinnet strike east by south or east-south-east; to the north-west of Schihallion, also, the strike is much disturbed.

This deviation of strike seems to be due to the intrusion of the "Newer Granite,"² which—unlike the "Older Granite"—is certainly posterior to the schistosity movements. The newer granites are unaffected by these movements, and are unfoliated, though lines of crush and fault, due to later movements, may traverse them; the older granites are foliated, that is, have their mineral constituents crushed and drawn out in determinate directions (Map 2).

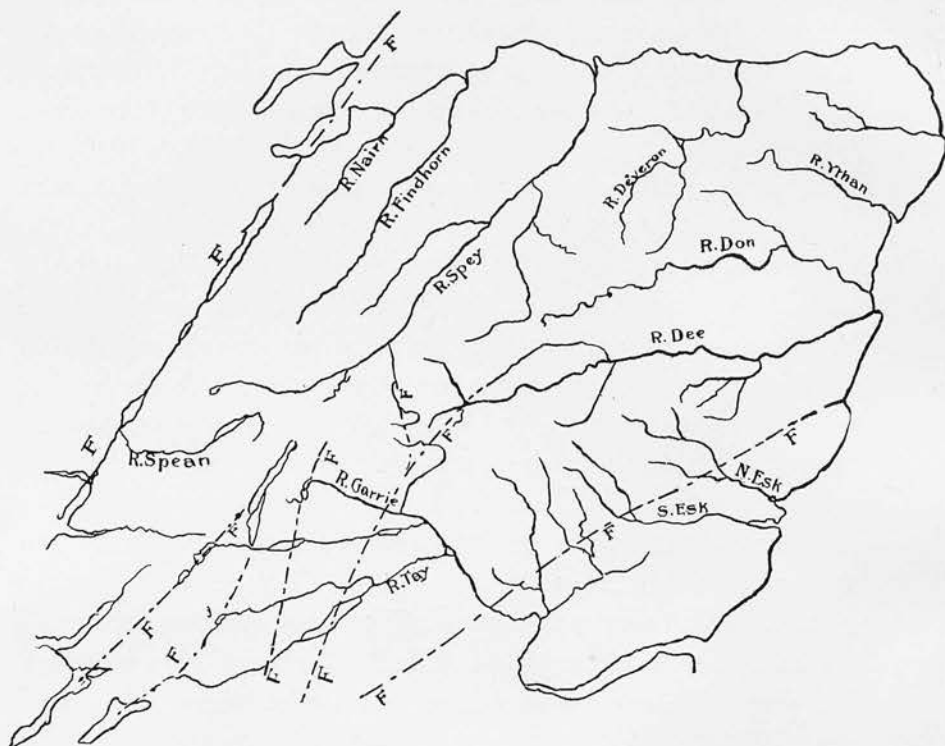
Is it not, then, reasonable to suppose that (probably in Silurian times or even later) the Central Highland area buckled up under the stress of powerful earth-movements? In that part of it which is now the Eastern Grampians, folding took place obliquely to the grain of the country—to the original strike or lie of the schists.

¹ For history of Tay see Sir A. Geikie's *Scenery of Scotland* (3rd ed.), pp. 190-91, 374-76.

² *Sum. Prog. Geol. Survey*, 1898, and subsequent years.

Into the axes of the east and west folds were injected the granitic cores that, now partially exposed by denudation, flank the Dee Valley.¹

A tectonic hollow—it may have been quite shallow—was produced, which guided the waters of the primeval Dee, and determined

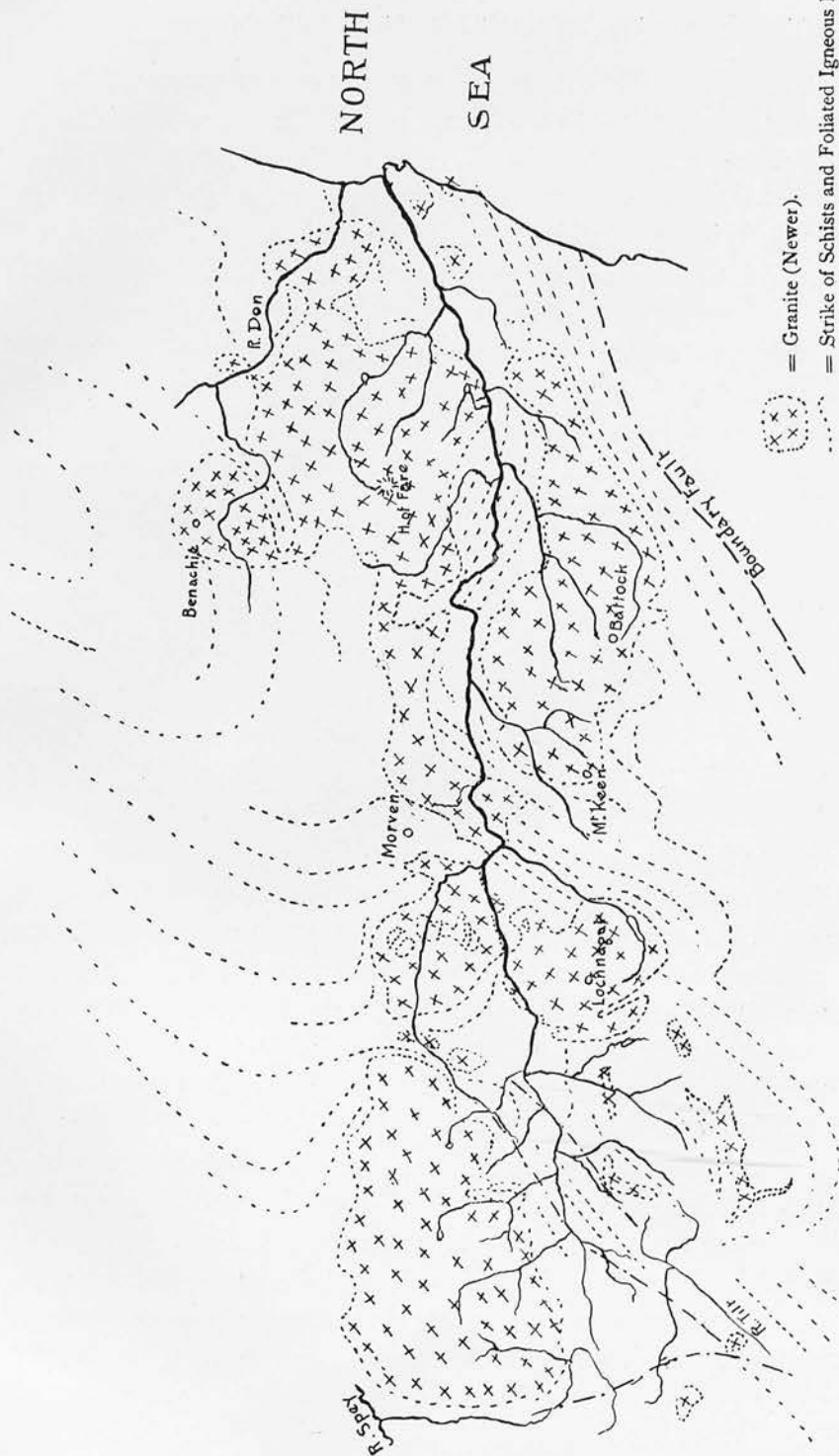


MAP I. . . River Map of the Central Highlands.

F F. = Faults.

the general course that the river through all subsequent changes has continued to follow. At all events the greater part of the course of the river lies between two elongated granitic intrusions, mainly

¹ Different portions of the newer granite of the Eastern Grampians may have been intruded among the schists at different times.



MAP 2.—Geological Sketch-Map of Basin of River Dee, generalised from 1-Inch Sheets of the Geological Survey Maps. Scale, 1" = 12 Miles.

exposed by denudation, but partly—from Lochnagar westwards—indicated at the surface by small bosses of granite, by broad sills and dykes of quartz-porphry, and by disturbance of the schists.

The granite is rarely cut across by the stream, and where this does happen, it is some projecting tongue of the great intrusions or connecting link between them that has thus been dealt with. This singular avoidance of the granite by the river seems to indicate that it was originally guided into its course by some feature produced at the surface by the plutonic igneous masses (Fig. 1).

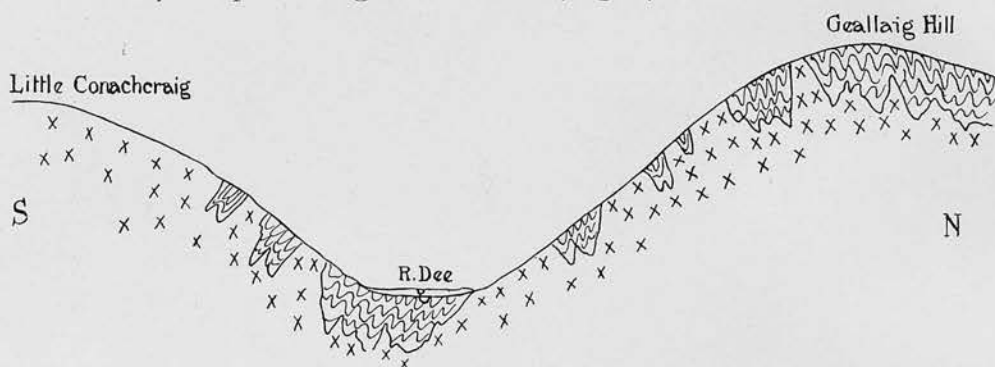


FIG. 1.—Diagrammatic Section across R. Dee at Balmoral (Distance = 5 Miles).
Crosses = Granite. Wavy Lines = Schists.

Another hypothesis that may account for the origin of the Dee Valley, is that during long-continued denudation the granite, owing to its superior resistance, gradually emerged from the wreck of the Highlands; and that the river now flows between two granitic ridges because the agents of disintegration have failed to remove them as readily as they have done the surrounding rocks.

There is still another reasonable hypothesis. During Old Red Sandstone times the Central Highlands were submerged to a great but unknown extent, and swathed in a mantle of sandstones and conglomerates. When the area recovered from this submergence, the seaward courses of the rivers lay largely over a platform of Old Red Sandstone deposits which, with the exception of a ragged fringe along the coast, and a few outliers in the interior, have since been removed by denudation. Rivers might thus choose and continue to keep a

course determined by the general slope of that part of the platform across which they began to trench their valleys—a course perhaps discordant with the lie of the rocks now exposed at the surface.¹

Which of these hypotheses affords the best explanation of the facts it may be hard to say.

The first, and the first alone, accounts not only for the origin of the valley but for the abnormal strike of the schist bands in the Eastern Grampians (of which indeed it is the only feasible explanation) and for the discordance between the direction of the Dee and that of neighbouring rivers. But whether the tectonic hollow postulated ever existed is uncertain.

For the second there is this to be said, that all the highest summits of the Eastern Grampians lie within the granite area, and in their present form are presumably mountains of circumdenudation—monuments of the superior resistance the rock of which they are composed has offered to disintegration. But in many parts of the world we find rivers flowing across granite bosses. To find a river so evidently controlled by ridges of granite as the Dee is suggests that in this case the granite *did* originally produce a feature at the surface.

The third hypothesis may contain a measure of truth. But we must recollect that many streams whose valleys were certainly buried under sedimentary deposits have, since the baring of the original features of the country by denudation, resumed in whole or in part their ancient channels; and the origin and direction of these still require to be accounted for. The Nith is older than the Permian Strata that partly fill its valley:² the Fiddich at Dufftown occupies a valley that existed before the deposition of the (Middle) Old Red Sandstone on which rest the foundations of the railway viaduct.³ I have found a boulder of Red Sandstone, exactly similar to the Old Red Sandstone of Fountainhall Road and other places in and near Aberdeen, at

¹ Sir A. Geikie, *Scenery of Scotland* (3rd ed.), p. 191.

² Geikie, *Scenery of Scotland* (3rd ed.), pp. 178, 335.

³ *Memoirs of Geol. Surv. of Scot.*, Explan. of Sheet 85 ("Geology of Lower Strathspay").

a point five and a half miles west of the city and within the present valley of the Dee. A single boulder obtained from a heap of field stones may not be much to found upon, but its occurrence would seem to suggest that at any rate the lower valley of the Dee, once partially filled by Old Red Sandstone, has since been re-excavated by the river, and is older than (Middle?) Old Red Sandstone times.

II. THE GRADIENT OF THE RIVER BED.

The profile of a river that has attained its regimen (*i.e.*, which is neither eroding nor depositing material) is a gently sloping curve that becomes flatter as the river-mouth is approached. The larger the river the flatter the curve, because the amount of erosion effected is greater (Fig. 2).

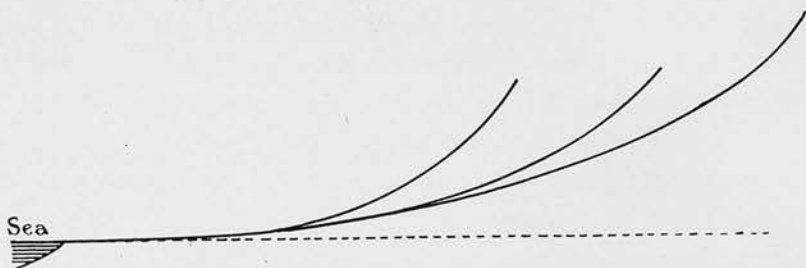


FIG. 2.—The Regimen of a River and its Tributaries.

Where hard rocks cross the valley, the river has more work to do and is longer in attaining its regimen. Here in a young river the profile curve is steep. Further up-stream, where softer rocks are being acted on, the curve flattens. In time the hard rocks are cut down and the whole curve becomes normal. But while this state of things is being brought about, the river has time to work on the softer rocks not only vertically, so as to deepen its valley, but also laterally, so as to widen it. The final result is the production of close gorge and open reach to which reference will be made later.

The plotted profile of the Dee (Fig. 3) shows that, from the "Wells" on Braeriach to where the Garchory Burn bends round to enter Glen Dee almost on the 2,000 feet contour line, the river makes a tremendous drop of 2,000 feet. Here and in Glen Dee farther

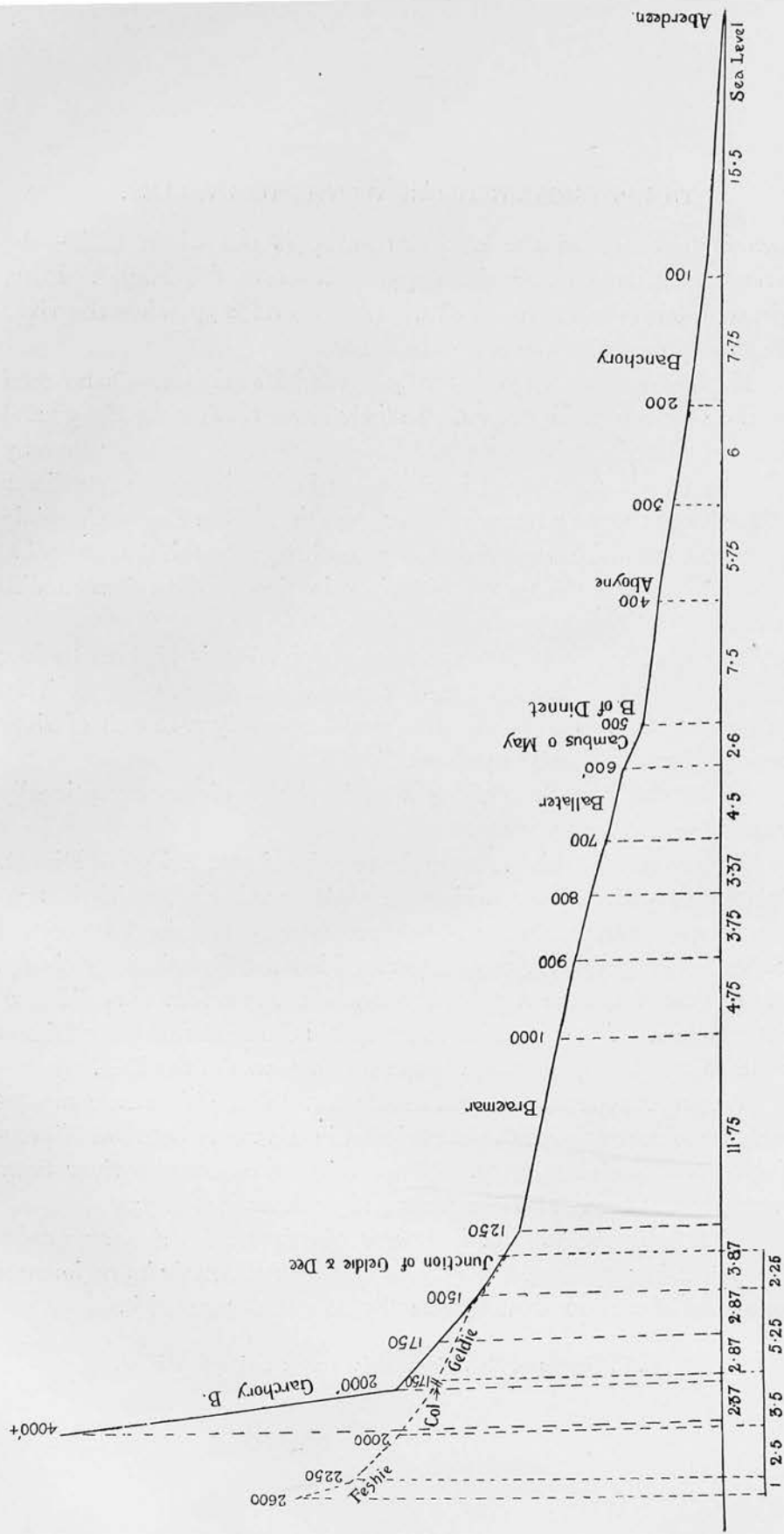


FIG. 3.—Profiles of River Dee and Feshie-Geldie. Horizontal Scale, 1" = 10 Miles. Vertical Scale, 1" = 100'.

down is to be found the wildest scenery in the whole basin—the corries of Braeriach and the scarped fronts of the Angel's Peak, Cairntoul, and the Devil's Point. In the first 2·37 miles the river falls as much as in all the rest of its course.

Even if we disregard this truly torrential section, it will be seen that the Dee is a rapid stream. In their lower reaches the Spey¹ and Don, neighbouring rivers, have falls of 16 feet per mile or thereby while the Dee has a fall of only 6·45 feet; but farther up the gradients of these two streams are much lower than that of the Dee. Certainly the statement which long found a place in geographical text-books, that the Spey was the most rapid river in Scotland, requires modification.

The gradient between 1,250 feet and 900 feet is abnormally low (see p. 25). This section includes the whole of the comparatively open valley above and below Braemar—as lovely a stretch of river scenery as can be found anywhere.

From the 600 ft. to the 500 ft. level there is an exceptionally steep fall—38·4 feet per mile.

To account for this we have the rock-barrier at Bridge of Dinnet. This probably caused a considerable rapid or waterfall, which has cut its way up-stream; but the river above has not yet attained the normal gradient. In addition a great amount of detritus, deposited here in the later phases of the Ice Age, had to be removed before the solid rock was attacked. The deep channel eroded in the solid rock near Dinnet is the most typical rock-gorge in the whole course of the Dee.

About Aboyne also the gradient is low. There is here a comparatively open reach above the constriction in the valley between Kincardine o' Neil and Banchory. Between these places the river flows over specially hard quartzose rocks and gneisses (see p. 73).

From Kincardine o' Neil downwards the profile shows a gradually decreasing gradient. The river is verging towards its regimen or base-level of erosion, though it has by no means reached it.

¹ L. V. Hinxman, *Scot. Geog. Mag.*, 1901; and appendix 1b.



Photo by J. Mathieson.

VIEW A.—The Corries at the head of the Garchory, Ben-y-Gloe in the far distance. The Allt an Garbh Coire (Dee) flows beneath the snow in the foreground.



Photo by C. E. Campbell.

VIEW B.—The Pools of Dee, Cairntoul and the Devil's Point in the background.

III. CAPTURE OF THE HEAD-WATERS OF THE RIVER BY TRIBUTARIES OF THE SPEY AND TAY.

Below the junction of the Geldie and the Dee, the direction of the united stream is that of the Geldie. The valley of the Geldie, moreover, is the wider and flatter.¹ This is anomalous. One expects the main stream to have the wider valley and to maintain its direction.

In explanation of this anomaly it may be said that the Dee above the junction has expended most of its energy in deepening its valley and has had little to spare for widening it. This may be granted, but the gradient of the Geldie Burn is markedly less than that of the Upper Dee, *i.e.*, it has more nearly reached the base-level of erosion. The width and slope of the valley can only be explained on the supposition that the stream occupying it is older than the Upper Dee.

But there is more to be considered. It has been shown by Mr. Hinxman that the original head-waters of the Geldie are to be looked for in those of the Feshie; and that we have here a clear case of the beheading or capture of one stream by another.² Even yet the col where the two streams approach each other is only a few feet above either—the capture must be comparatively recent.

The original Feshie had a rapid descent towards the Spey. It ate its way back into the gathering ground of the Geldie and drew off the upper section of that stream, over six and a half miles in length, to swell the volume of the Spey.

Further, though Mr. Hinxman does not discuss the point, there is every probability that the Eddart once was tributary to the original Geldie—the Feshie-Geldie as it may be called—and sent its waters down to the North Sea by way of the Dee. The whole appearance of the valley between the mouth of the Eddart and the col between the Feshie and Geldie suggests this.

Swelled by the Upper Feshie and Eddart, the Geldie would be a powerful stream; and the magnitude of its valley is partly explained.

¹ See Profile and Sections of Feshie-Geldie, Figs. 3, 4 and 6.

² *Scot. Geog. Mag.*, 1901.

The mere depth of a valley is in itself no mark of extreme age. A rapid stream may in a comparatively short time cut a deep, steep-sided trench in solid rock. Weathering will tend to reduce the slope of the sides. Especially will the wedging action of water freezing in cracks and joints shoot down rubbish to be swept away by the stream below. The older the valley the more pronounced will be the effect of weathering; and from being V-shaped in cross-section it will gradually assume the flowing curves we are accustomed to look for in a river valley. Ultimately, too, weathering will lower the bounding hills, so that width rather than depth is the true indication of a valley's age.¹ Judged by this standard, Glen Dee is youthful compared with the valley of the Feshie-Geldie (Figs. 4, 5, 6).

The Feshie-Geldie, which is a direct continuation of the course of the Dee from the mouth of Glen Dee downwards, was the older—the parent—stream; the Eddart and Dee (Glen Dee and Garchory section) originated as lateral streams on the northern boundary ridge of its valley. They have cut back into that ridge, annexing territory, and lengthening and deepening their valleys, till they almost equal the parent stream in length, and certainly surpass it in impetuosity if not in volume (Maps 3 and 3a).

There is still another point of great interest in connection with the upper part of the Dee Basin. A wide valley runs from the mouth of the Geldie to the top of Glen Tilt. The pedestrian who takes the bridle-path for Blair Atholl with the graceful quartzite cones of Ben-y-gloe in front, braces himself for a stiff climb, thinking that he will have to cross into Glen Tilt high up on the shoulder of that mountain. Instead, after an almost imperceptible ascent, he finds himself on the down grade and descending a glen that narrows and deepens as he proceeds.

¹ The only exception to this is the case of a river of "recent" origin occupying a flat syncline where the breadth of the valley from watershed to watershed will be the expression not so much of the amount of erosion and weathering as of the extent from crest to crest of the earth-waves producing it (*e.g.* Thames: see Strahan, *Quarterly Journal of Geolog. Soc.*, 1902, "Origin of the River System of South Wales").

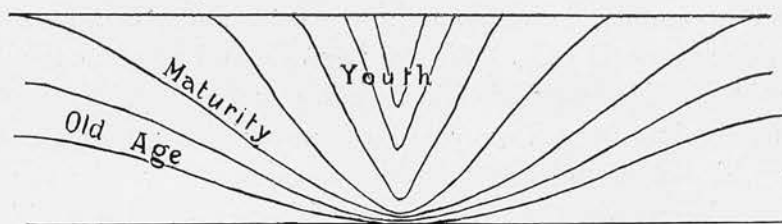
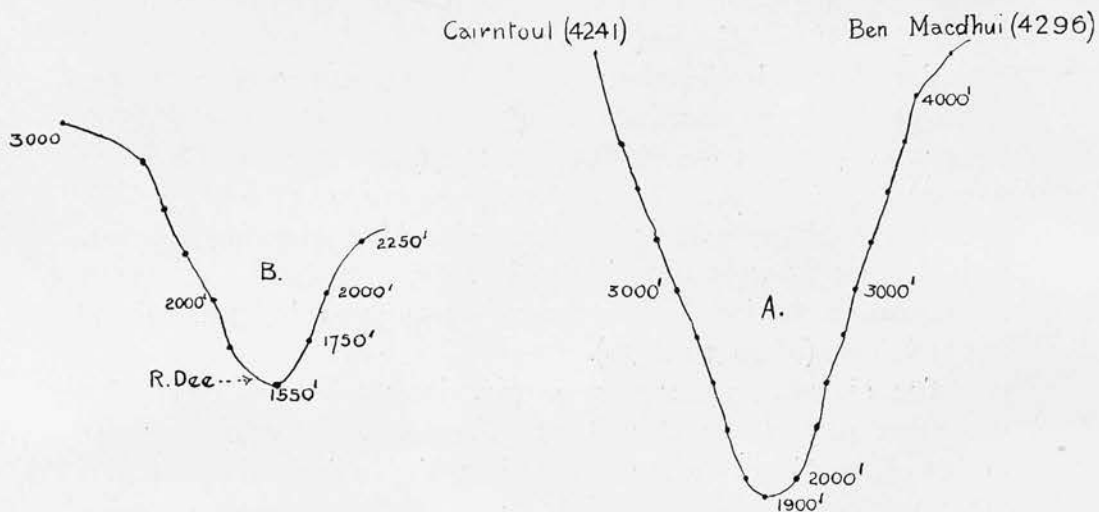
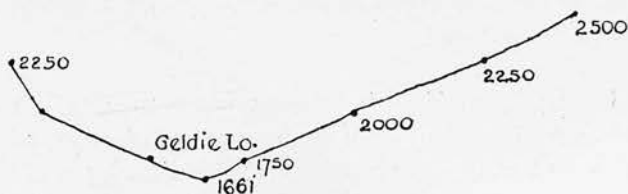
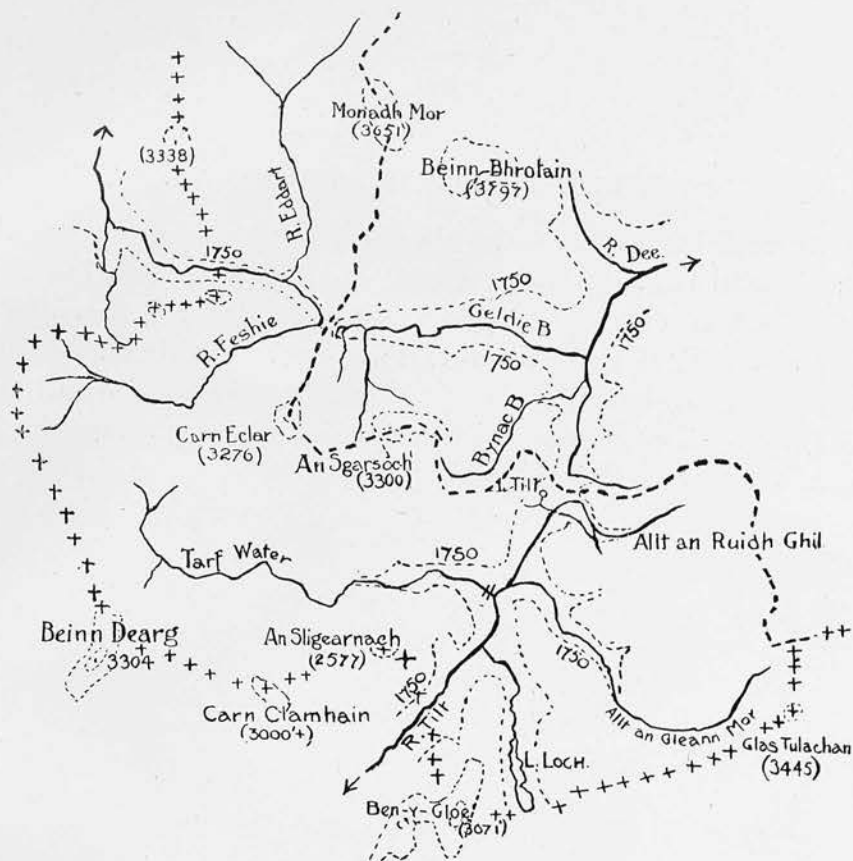
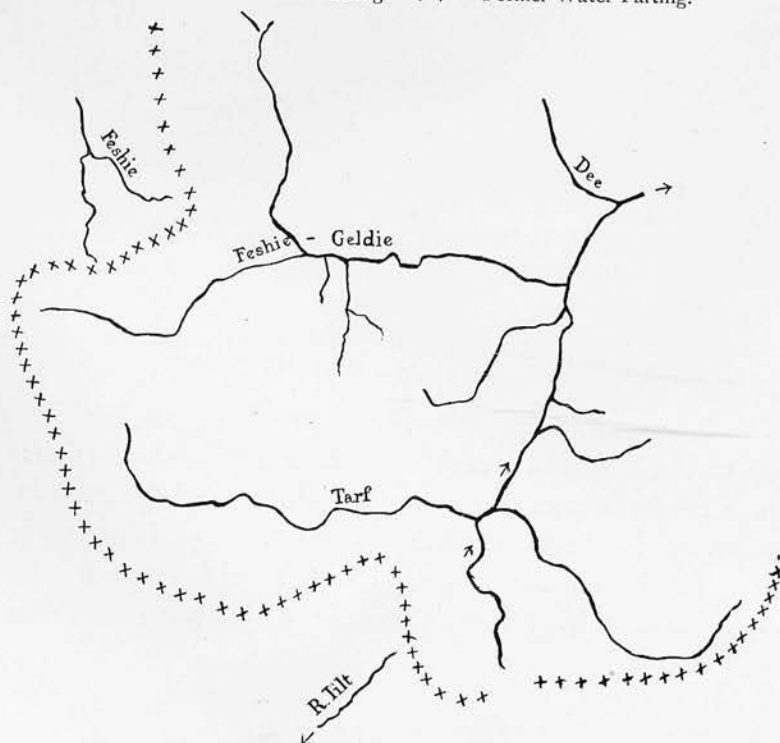


FIG. 4.—Diagrammatic Sections across a River Valley at Different Stages in its History.

FIG. 5.—Sections across Glen Dee. Horizontal Scale, $1'' = 1$ Mile. Vertical Scale, $\frac{1}{16}'' = 100'$.FIG. 6.—Section across Geldie Burn from S. (left) to N. (right). Horizontal Scale, $1'' = 1$ Mile. Vertical Scale, $\frac{1}{16}'' = 100'$.

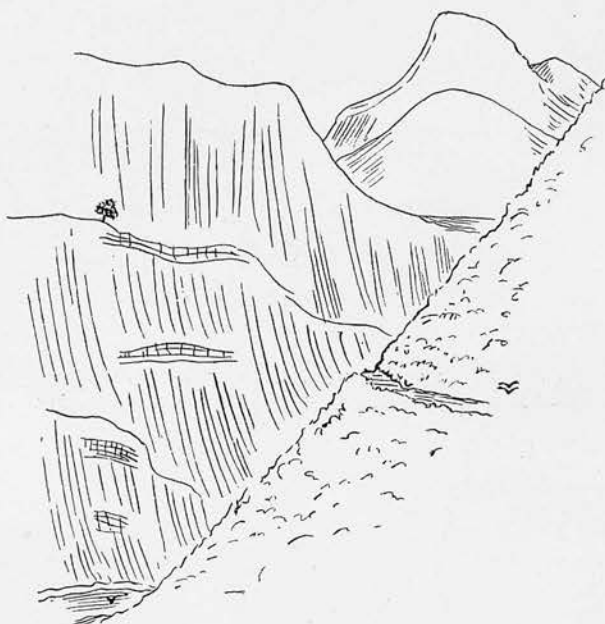


MAP 3.—Map Showing Adjoining Portions of the Basins of the Dee, Tay and Spey.
 . . . = Present Water-Parting. ++ = Former Water-Parting.



MAP 3a.—Map Showing the Former Drainage of the Area represented in Map 3.
++ = Water-Parting.

By referring to the map (Map 3) it will be seen that the An Lochain from L. Loch bends round to join the line of Glen Tilt at an angle of about 125° , the Allt an Gleann Mor through an angle of 90° , and the Tarff through an angle of 135° . The united streams pour impetuously through a V-shaped gap in a ridge which in Beinn a Glo (Ben-y-gloe) rises to a higher elevation than any summit in this district south of the Cairngorms.



View from Glen Tilt Bridle Path, looking S. towards Ben-y-Gloe.

✓ = Allt Garbh Buidhe, occupying the whole bottom of the Glen.

≡ = Bridle Path.

The E. side of the glen consists of cliff and scaur.

VIEW C.

The explanation that I would offer of these peculiarities is this. The Tarff, An Lochain, and Allt an Gleann Mor were originally the head-waters of a stream that flowed to join the Geldie and carved out the well-marked valley along which now runs the bridle-path.

The Tilt began as a mountain burn flowing down the southern slope of a ridge uniting Carn Clamhain and Ben-y-gloe. It gradu-

ally cut its way back into this ridge, finally tapping and drawing off the waters of what were then very important feeders of the Dee.

Once this took place, the increased volume of water drawn towards the Tay helped to cut still deeper the valley of the Tilt. The upper waters of the beheaded streams had now a shorter and steeper course towards the sea and their erosive power was increased. Those streams that had already approached their base-level of erosion were rejuvenated. This may account for the great gash cut in the Highland schists by the Allt an Gleann Mor, and for the gorge-within-a-valley that characterises the lower course of the Tarff.

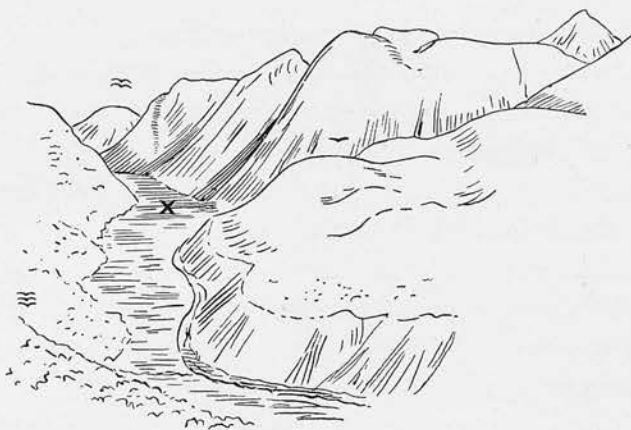
The final act in the drama of stream-life in this quarter is of comparatively recent date. The Allt an Ruidh Ghil descends from the south-east upon the watershed in the valley bottom close to the county boundary-line. It has deposited a considerable alluvial fan. When it reaches the top of this the stream curves round towards the south-south-west in the direction of the Tilt. About a third of a mile lower down it is joined by the stream from L. Tilt,¹ and this part of its course lies in a steep-sided, evidently recent trench. On the alluvial fan can be traced a former stream-track heading towards the Dee, so recent that, though excavated in incoherent gravel, it is still unobliterated. The fan has switched off the Allt an Ruidh Ghil towards the Tay.

Whether the above be the true explanation or not, the valley south of Bynac Sheiling certainly requires to be accounted for in some special way. Though evidently water-eroded, it positively could not have been carved out by the dribble of water that now flows from the boggy watershed to join the Dee. Its *direction* may have been determined by the minor faults and shattered rock in the neighbourhood of the Clais Fhearna Fault which runs parallel with it to the west.²

It is therefore likely that sixty-nine square miles of territory have been filched from the upper basin of the Dee. Of this area the capture

¹ The united stream is named on O. S. maps Allt Garbh Buidhe.

² So far as I know, there is in geological literature no reference to the remarkable valley-system of this district.



View from Glen Tilt Bridle Path, looking N

~ = Allt an Ruidh Ghil.

≈ = Valley leading to Dee.

≡ = The Tilt.

x = Watershed and County Boundary Line.

VIEW D.



View from Watershed between basins of Dee and Tilt looking N. towards the Cairngorms.

~ = Glen Dee, ≈ = Glen Geldie.

VIEW E.

N. of Coire an Loch
(2457')

N. of Sron a Bhoididh

2250'

2000'

1750'

FIG. 7.—Section across the Valley a little to the N. of L. Tilt.
Horizontal Scale, 1" = 1 Mile. Vertical Scale, $\frac{1}{10}$ " = 100'.

of the Geldie by the Feshie (which is undoubted and comparatively recent) accounts for eleven and a half, the capture of the Eddart for thirteen and a half, and the capture of the Tarff and other streams for forty-four square miles.

It may be well, while we are discussing the diversion of streams by capture, to deal here with the beheading of the Slugain Burn by the Quoich.

The original streams descended in a south-east direction from Beinn a Bhuid. The Middle Quoich began as a lateral stream tributary to the more westerly of the two. Eating its way back, a process in which it was doubtless assisted by the line of weakness caused by the Clais Fhearna Fault, it tapped the Slugain, and the present drainage was established (see pp. 60-63).

IV. RELATION BETWEEN THE COURSE OF THE RIVER AND ITS TRIBUTARIES AND GEOLOGICAL STRUCTURE.

As already pointed out (p. 3) the course of the Dee is neither transverse nor longitudinal. For short distances it may follow the strike or, especially where the rocks are particularly resistant, cut directly across it. But no obvious relation can be traced between the strike of the rocks and the general course of the river; and, generally speaking, the same is true of its tributaries.

The Upper Ey and Upper Clunie and their feeders, however, show a decided tendency to follow the outcrops of the softer and more readily eroded rocks—Black Schist, Calcareous Schist, and Crystalline Limestone.

Faulting has had a more evident effect on the direction of stream and valley than the strike of rocks.

From Glen Tilt to Carn More a valley follows the direction of the Clais Fhearna Fault though it does not exactly coincide with the line of fracture. Similarly near Braemar the Dee drops almost into the line of the great fault that here runs obliquely across the valley.

The relation between the Clais Fhearna Fault and the course of the Middle Quoich has already been pointed out (p. 19). The same

fault evidently determines the direction of the Upper Gairn from the col between Glen Quoich and Glen Gairn down to the south end of L. Builg. The line of weakness produced by rock-shattering may also help to explain the depth of the impressive gap that separates Craig na Dala Beg and Craig na Dala Mor.¹

V. EFFECTS OF ICE ON THE PHYSICAL FEATURES OF THE VALLEY.

Since the origin of the Dee Valley, whatever period we assign that origin to, many changes of drainage and surface feature must have taken place within it. Some of these we can trace, some we can merely guess at. A very long time must have elapsed since the main features of the river basin were blocked out. Before the advent of the Ice Age the country had acquired physical features differing in no essential respect from those it possesses at the present day. Yet when any district is closely examined it will be found that there has been a very great modification in detail.

If early man ever roamed on the banks of the pre-glacial Dee, he would find considerable difficulty, even if he possessed an "eye for country," in recognising the scenes of his pre-historic exploits were he to revisit them now.

Deeside is still sufficiently picturesque to attract crowds of visitors every year; but before the Ice Age it probably was much more rugged and diversified in surface. From the Cairngorms to Girdleness there is not a hill but has had its craggy sides and rugged summit rounded and abraded by the mighty ice-plane; while many a valley has been partially filled by the bottom-moraine or boulder-clay left by the retreating ice. Though the scooping action of glaciers may have helped to fashion the great corries of Lochnagar and the Cairngorms, the added grandeur of the more inaccessible regions hardly compensates for the comparative featurelessness of the ice-abraded, hog-backed lower hills.

We can have little conception of the pre-glacial appearance of the basin of the Dee. Even its early post-glacial features have been greatly

¹ But see p. 69.

modified. The hand of Nature, operating through rain and rivers, has been actively at work, filling lakes and retrenching valleys. By the hand of man lakes have been drained, erratic boulders blasted and removed, and land brought under tillage.

At the climax of the Ice Age the ice-field that fed that part of the ice-sheet which moved towards the North Sea in a direction somewhat north of east and followed the general trend of the Dee Valley, lay over the high plateau drained by the upper tributaries of the Dee and the neighbouring tributaries of the Spey and Tay, but was deepest over the ground rising northwards to the Western Cairngorms and bounded on the south by the ridge (breached by the Tilt) running north-west from Ben-y-gloe by Ben Dearg.

That this area, which now has a heavy rainfall and probably had in glacial times a heavy snowfall, was the great centre of dispersion is proved by the glacial phenomena of the Western Cairngorms. Within the granite area near Lochan-nan-Cnapan, on the high ground above the head of Loch Eunach, are moraines consisting almost entirely of materials (non-granitic) from the south. The same materials, largely mixed with blocks of granite, are found in the moraines of Glen Eunach. This clearly proves that the Cairngorms were not during the maximum glaciation an independent centre of dispersion.¹

Similarly it may be shown that the Lochnagar massif did not at this period act as an ice-shed. The glacial detritus of Glen Gironck contains abundant fragments of rocks from the west of Lochnagar; and even under the shadow of Conachraig fragments of quartzite and garnetiferous hornblende schist can be picked up, which the later phases of glaciation, during which Lochnagar and in fact all the higher hills in the basin of the Upper Dee acted as centres of dispersion, have failed to clear away.

As the ice streamed eastward probably not a single nunatak broke its surface. Dr. T. F. Jamieson has recorded² fragments of Cairngorm granite from the top of Morven (2,862 feet), and the present writer has

¹ *Sum. Prog. Geol. Surv.*, 1897, pp. 147-48; 1902, pp. 102-3.

² *Brit. Assoc. Rep.*, 1859.

gathered pieces of quartzite, such as abounds to the westward, near the very summit of the hill. Morven itself is composed of greenstone (epidiorite) with a few patches of serpentine. How high the ice rose over Morven there is, of course, no means of telling, so that its actual thickness can only be matter of conjecture.

1. *Ice-abrasion*.—Morven, then, was overridden by ice, and not a hill within the basin of the Dee eastward of it has escaped glaciation. This is true both of the hills that form the main watershed and of those that form the minor watersheds. The smooth flowing lines that everywhere meet the eye in a distant view are the direct result of the passage of the ice-sheet.

Craigendarroch is an excellent example of abrasion by ice. The steep western face of the hill is plastered for fully 100 feet above the river with boulder-clay: but from between 800 and 900 feet above O. D. to the summit it is one huge *roche moutonnée*. The eastern face, protected from the abrading action of the ice, is bare and rugged, and exhibits the characteristic weathering of the granite of which it is composed.

At the south end of the Cnoc Dubh Ridge, just north of Cambus o'May Station, acres of bare ice-worn granite are exposed.

The gneiss hills that form the watershed between the Tarland Burn and the Dinnet Basin, when viewed from the north, exhibit to perfection the flowing lines of ice-worn hills; and bare *moutonnée* surfaces occur abundantly. Closer inspection reveals the fact that the naturally craggy surfaces have been in some measure retained.

On the ridge that separates the Lumphanan and Torphins basins and runs eastward to form the watershed between the Dee and its tributary the Beltie Burn (Burn of Canny), glaciated surfaces are frequent and well preserved. An excellent example is to be seen at Stranduff.

But it must be remembered that most of the rocks of the Dee Valley are not of a nature fitted to take or retain the finer ice-markings. Striæ need hardly be looked for except on the harder and finer-grained rocks. Granite and gneiss are often merely smoothed or

polished without striation: sometimes both they and other rocks may be marked by coarse furrows, though the writer has observed none on Deeside.

Striæ and larger grooves, flattish, smoothed surfaces, and *roches moutonnées* are alike due to the passage of rock-fragments, large and small, pushed along beneath the ice or frozen into its sole.

Polished granite surfaces soon become roughened by the action of the weather, and can only be seen to perfection on rock that has been protected by a covering of turf or boulder-clay. A good example was displayed some years ago in a granite quarry on Hill of Coull, and a fair example may be seen at Cairncry Quarries.



Photo by J. Mathieson.

VIEW F.—Ice-worn Granite at Cairncry Quarries.

To multiply examples of ice-abrasion is superfluous. All the hills from Ballater to the sea appear even to the untrained eye to be ice-worn. Among the higher hills weathering has since the close of the Ice Age removed nearly all the ice-markings. There and there only in the area under discussion can be studied the characteristic forms yielded by rocks exposed to the action of weathering alone. Elsewhere the

forms are still for the most part masked by what has been called the "Sand-papering" of the Ice Age. The full effect of this upon the scenery of Deeside can hardly be realised by anyone unacquainted with an unglaciated area occupied by similar rocks.

2. *Ice-Erosion*.—It is sometimes assumed that ice can excavate valleys where none existed before and in this way alter the drainage of a country. No direct and conclusive evidence can be adduced to prove the truth or even the probability of such an assumption. That ice can widen and deepen pre-existing valleys has been abundantly proved. Good examples of this form of ice-action are to be found within the Dee Valley.

Where the pressure of ice is greatest, there erosion will be at a maximum. Seeing that the ice-sheet moved persistently east by north along the basin of the Dee, all parts of the valley of the main stream and of the valleys of its tributaries that trend in this direction may be expected to exhibit signs of ice-erosion. Those at right angles to the ice-movement have escaped, and have, in fact, been in many cases partially blocked by accumulations of boulder-clay.

But the ice-movement varied. During the valley-glaciation it was in the main down the glens. In the more elevated districts glaciers lingered late, and there the valleys and corries were subjected to strong erosion.

The evidence in support of the view that corries in glaciated areas, especially such as hold lakes, owe their present form to ice-action has so often been given that it need not be restated here. Lochnagar, Dubh Loch, Loch Etchachan, Loch-an-Uaine and other high-level corrie-lakes owe part of their depth to moraine dams, but probably all lie partly in true rock-basins scooped out by ice.

The case of Loch Muick is interesting. It lies in a wide and deep basin, evidently the bed of a vanished glacier, the overwash deposits and degraded moraines of which seem to act as a dam to the waters of the lake. The intensely ice-worn rocks at its eastern end (south side) and the marked constriction of the valley lower down point to the intense glaciation of this hollow. When the Bathymetrical Lake Survey

extends to Aberdeenshire,¹ Loch Muick will no doubt be found to occupy a true rock-basin, for it is known to be very deep, and rock crosses the Muick not more than 100 feet below the surface-level of the loch (1,310 feet).

Glen Geusachan, the Garchory and Glen Dee (especially its upper part) are peculiar. Instead of the **V**-shape typical of the valleys of mountain torrents we find a distinctly **U**-shaped cross-section. As examples of the erosive power of water such as one might expect to find here, these valleys are disappointing: the gorges of the Tilt and Feshie are far more typical and impressive (Fig. 5, A, B; Fig. 8, A, D, E).

The **V**-shape due to stream-erosion has disappeared: the **U**-shape characteristic of ice-erosion has taken its place. Only in narrowness and depth are Glen Geusachan, the Garchory and Glen Dee in harmony with the gradients of their streams.

No one, in particular, can observe how the waters of the infant Dee (the Garchory Burn) and the streams from the hanging corries overlooking the Garchory slip down bare rock-faces, on which they have scarcely managed to trace a well-defined channel, without coming to the conclusion that water has played but a minor part in the production of the great hollow of the Garchory.

Above and below Braemar large glens open into the Dee Valley. Each of these in late glacial times has poured its tributary stream of ice into the main valley. In it the thickness, pressure, and erosive power of the ice must have been enormous. Hence, partly, the flat bottom and **U**-shape of the valley in this section of the river.

¹ Since the above was written (1903) L. Muick has been surveyed. Its maximum depth has been found to be 256 feet. The present bottom of the loch lies 50 feet below the rock at the lip of the linn and considerably more below the highest point at which rock can be seen crossing the bed of the Muick. Thus, making no allowance either for the raising of the bottom-level of the loch by deposition of sediment or for post-glacial erosion of the rock-barrier by the river, we know that the deeper parts of L. Muick occupy a true rock-basin. See *Bathymetrical Survey of the Fresh-water Lochs of Scotland*, pp. 146, 147; "On the Formation of Certain Lakes in the Highlands," *Proc. Roy. Soc. Edin.*, vol. 26 (1906).

Separated by a narrow ridge from the valley of the Dee at Invercauld Bridge is a hollow that extends by Felagie and Middleton of Aberarder to Balnoe. This valley is wide, flat-bottomed and largely

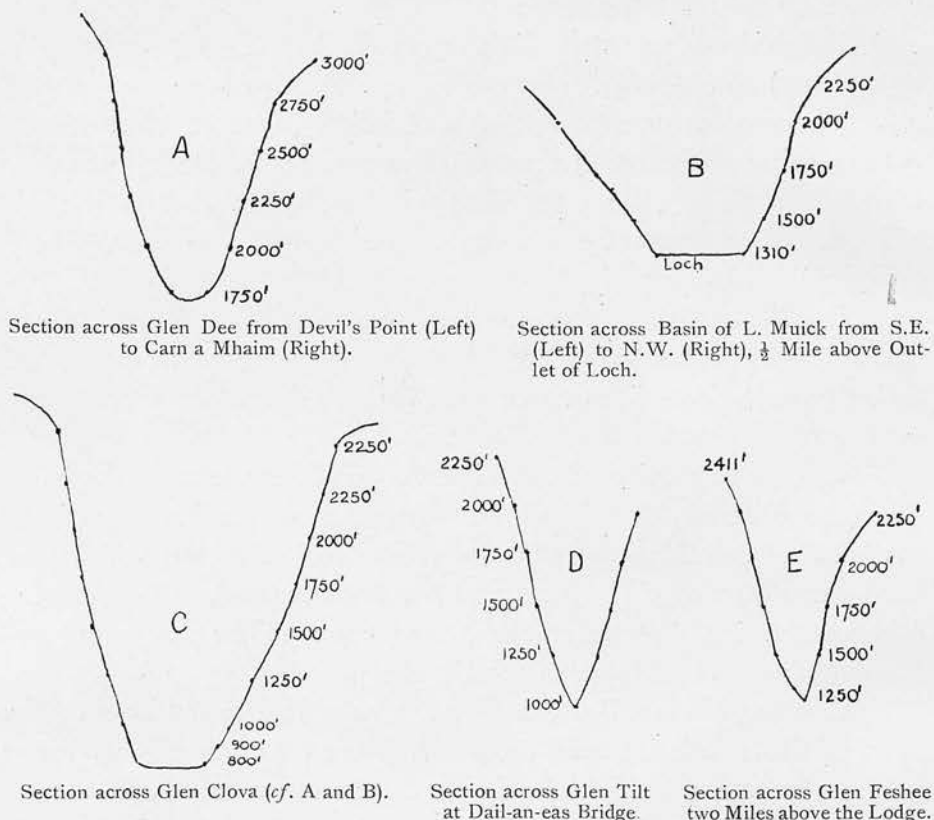


FIG. 8.—Sections Illustrating the Difference between Valleys that have been subjected to Ice-erosion (A, B, C) and (mainly) Water-eroded Valleys (D, E). Horizontal Scale, 1" = 1 Mile. Vertical Scale, $\frac{1}{8}$ " = 100'.

occupied by peat dotted with lochans. The stream that occupies it—a tributary of the Fearder Burn—is a mere thread of water quite incapable of carving out a valley of such magnitude and gradient. Clearly the ice streaming out of the Braemar Basin has divided, one part passing down the Dee, the other along this hollow which it has helped to widen and deepen.

Visitors to the Colonel's Bed must have been struck by the pecu-

liar appearance of Glen Ey about Aucherrie. There is a wide U-shaped valley : along its bottom runs the gorge in which flows the Ey



Glen Dee, looking towards Braeriach.
Slopes of Ben Muichdhuì on right, of Cairntoul on left.
(Cp. Fig. 5A.)

VIEW G.



Photo by J. Mathieson.

VIEW H.—The Garchory looking towards Ben Muickdhuì.

Burn, its existence revealed only by the tops of trees that find a precarious hold on its rocky and precipitous sides. By some means the Ey has been rejuvenated in post-glacial times and has cut the deep

gorge along the bottom of the ice-modelled valley of the pre-glacial stream (Fig. 9).

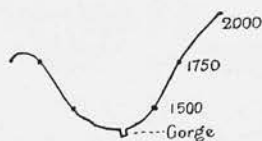


FIG. 9.—Section across Glen Ey, near the Colonel's Bed.
Horizontal Scale, 1" = 1 Mile. Vertical Scale, 1" = 100'.

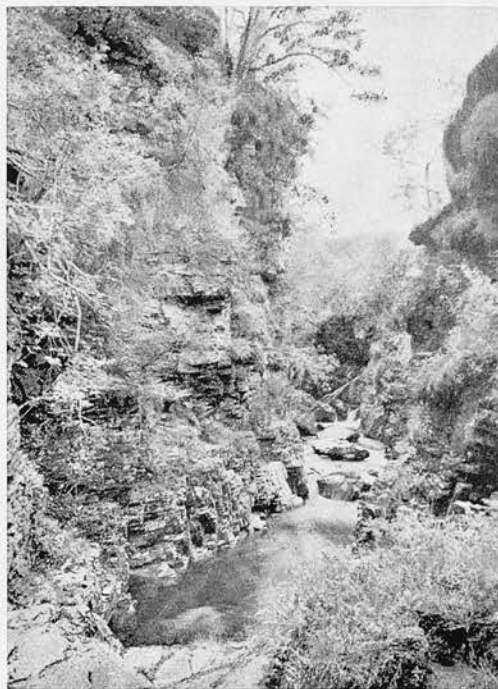


Photo by J. Mathieson.

VIEW J.—Gorge of the Ey Burn from the Ledge called the "Colonel's Bed".

The upper portion of Glen Ey from the great bend up to Alltandhar Shielling has the shape typical of ice-erosion—steep sides, flat bottom; the gradient of the stream, too, is here exceptionally low, 50 feet per mile, which is less than half the average fall between the 1,500 feet contour line and the junction of the Ey and Dee.

A wide hollow lies between Morven on the north and the granite hills, Culblean and Crannach Hill, with the epidiorite hill, Creagan

Riach, on the south. It is occupied by peat moss and sheep-pasture, and is drained by the Rashy Burn and other insignificant streams that unite to form the Tullich Burn. The outline sketch will show the discordance between the extent of the hollow and the size of the streamlets, as well as the curious way in which the latter quit the wide upper basin to breach the granite ridge.



Hollow S. of Morven

✓ = Rashy Burn.

W = Tullich Burn.

VIEW K.

We have here an instance of ice-erosion. The ice-sheet, divided by Morven, acted strongly on the valleys converging towards the head of the Tullich Burn so as to form the hollow in question, while the glens cutting across the southern ridge practically escaped glaciation—they ran at right angles to the ice-movement.¹ The hollow is open and flat-bottomed; the glen of the Tullich Burn is deep, narrow and V-shaped. The difference cannot be accounted for by the nature of the rocks out of which they have been carved.

The ice-sheet in its passage seawards overrode all inequalities of surface, but these had no little effect in modifying the motion of the lower layers of ice. That inequalities in the bed of a stream can affect the motion of the water is well known. A stream rushes with the full force of its current against a boulder. It is deflected downwards and to either side. A slight hollow is excavated in front of the boulder and for some distance along both sides. Similarly a hill rising

¹ During the "valley glaciation" ice streamed down the Tullich Burn and the Culsten Burn to join the ice that then occupied the Ballater Basin and deposited the lateral moraine mentioned on pp. 42 and 52.

abruptly from low ground will be intensely ice-worn on the steep face—the Stoss-seite—presented to the advancing ice. The opposite face—the Lee-seite—will be acted on but slightly. The ice-stream will excavate a deflection basin in front of and along both sides of the hill, while a tail of boulder-clay will tend to accumulate in its rear.

The relation between obstructing hill and deflection basin will be clearest when the hill rises abruptly from low ground. An excellent example is furnished by the Castle Hill of Edinburgh and the hollow that bounds it on the north, west, and south sides.

No such typical example is to be found on Deeside, but the hollows in which lay the lochs of Tarland and Auchlossan, now drained, appear to be in part due to this cause. The deflection of the ice in the Tarland Basin is shown by ice-markings—a deflection due to the high ground to the eastward. On Balnagowan Hill the *roches moutonnées* indicate an ice-movement towards the south-east; on Queen's Hill, the ice having here rounded the obstruction, to the east; on the obstructing ridge itself to the east.

Striæ, *roches moutonnées*,¹ and the distribution of erratics show that ice has at different times streamed both across and down the Strachan Valley. Its great width compared with that of the valleys opening into it (Upper Feugh, Aven, Dye) and the abnormally low gradient² of the part of the Feugh that drains it, can hardly be accounted for by the nature of the rock in which it has been excavated, though that has had a certain effect. It is to a large extent an erosion basin.

The Beltie Burn (Burn of Canny) probably once took a much more direct course to the Dee than it now does. It has been diverted and thrown on to rock through the filling up of its pre-glacial valley by a tail of boulder-clay running eastward in the rear of Hill of Beltie. The "tail" is very conspicuous, but without the aid of borings it is impossible to *prove* that it is composed of boulder-clay. Partly to this, and also largely to glacial erosion, may be attributed the wide, flat-bottomed hollow that stretches from Craignarb and Brathens to be-

¹ *Geol. Surv. Map of Scot.*, Sheet 66.

² Fig. 17, C (250'-300').

yond Torphins. Glacial abrasion has certainly acted strongly on the hills to the west and south.¹ The hollow exactly coincides with the direction of ice-movement: it is too extensive to be due solely to the action of the stream which now follows a "corrected" course through it. It is an example of a valley widened and deepened by the action of ice.

The Leuchar Burn, which drains the Loch of Skene, passes near the farm of Denmill through a rock-gorge fully 50 feet deep. The top of this gorge is almost exactly on a level with the outlet of the loch. From the commencement of the gorge by Broadwater and Leuchar Moss to Garlogie stretches an extensive alluvial flat, once a lake. Indications of terracing are not wanting.²

The gorge is certainly post-glacial; its sides are steep, in some places almost vertical; and no trace of boulder-clay is found within it. What course the pre-glacial stream took is uncertain. It possibly followed the direction of the hollow now occupied by the Silver Burn and Moss of Rotten, and so passed to the Dee in the neighbourhood of Murtle. But at the head of the Den of Murtle rock crops out in this hollow at a level quite as high as that of the Loch of Skene. Except the pre-glacial course be choked by boulder-clay—a view in favour of which there is some evidence—one is forced to the conclusion that the upper part of the basin of the Leuchar Burn has been subjected to intense glacial erosion and lowered below the level of its outlet. Till that outlet was cut down it was in post-glacial times occupied by a lake or lakes.

3. *Boulder-Clay*.—The influence of boulder-clay upon the scenery of the Dee Valley is almost everywhere apparent, and boulder-clay forms the sub-soil in most places.

Underneath moving ice, "and probably partly incorporated in the lower portions of the ice, there accumulated a mass of earthy, sandy, and stony matter . . . which, pushed along and ground up, was the material wherewith the characteristic flowing outlines and smoothed striated surfaces [of glaciated regions] were produced".³ This material

¹ Expl. of Sheet 76.

² Expl. of Sheet 76.

³ Sir A. Geikie, *Text-book of Geol.*, p. 1031.

—the bottom-moraine of glacier or ice-sheet—left behind on the dissolution of the ice, forms *boulder-clay* or, as it is called in its toughest form, *till*.

This residual material has been very irregularly distributed. It lies deepest on the low grounds, while hills and projecting knobs and bosses of rock exhibit bare ice-worn surfaces or are mantled by a thin coating of boulder-clay. Hollows have been filled up and inequalities of surface smoothed over. The flowing contours of a glaciated region are due to a levelling up as well as a levelling down. The levelling up would be promoted by the sheets of sand and gravel spread out on the low grounds by the Schmelzwasser from the retreating ice.

Wherever a prominence rose above the general level, boulder-clay would tend to gather behind it in a long ridge or *tail*, like sediment in the rear of a boulder in the bed of a stream.

Just as sediment in a stream tends to arrange itself in long banks parallel to the direction of the current, so on fairly open ground across which the ice moved with a comparatively free but differential motion we find its ground-moraine heaped up in long, low, sow-backed ridges or *drums* of boulder-clay. These trend in the direction of ice-movement.

Many interesting modifications of surface feature have been brought about by the irregular distribution of boulder-clay.

Scattered broadcast over the lower Dee Valley, particularly in the Skene and Echt districts, are patches of peat-moss and alluvium. Many of these represent vanished lakelets that have been obliterated either by natural processes or by drainage. They generally occupy hollows on the surface of boulder-clay.

Several larger sheets of water have a similar origin—the Loch of Skene,¹ Loch Davan,¹ and the Loch of Loirston (though there is a conspicuous moraine on its south-east side by which it is partially dammed).

Hardly a stream could be named which is not in some part of its course engaged in clearing away the boulder-clay by which its valley

¹ Expl. of Sheet 76.

was wholly or partially filled at the close of the Ice Age. The high bluffs between Dinnet and Aboyne, and elsewhere along the Dee, afford excellent sections of this deposit, and show how incompletely even the main stream has been able to scour out the glacial accumulations.

An excellent illustration of the manner in which boulder-clay may alter the pre-glacial surface was recently disclosed in making the sewer from the Dee to the Bay of Nigg (Fig. 10).

When streams began to flow as the ice finally melted away, the chances would be against the stream-lines of the post-glacial valleys, with their carpet of glacial detritus, coinciding throughout with the tracks of the pre-glacial streams. In post-glacial times rivers in many instances ran more or less to one side of their valleys or lost their way entirely,

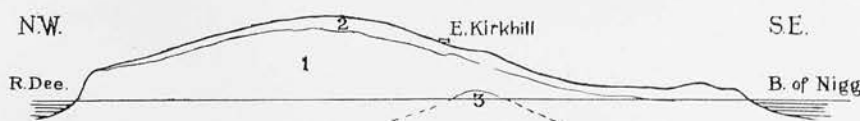


FIG. 10.—Section along St. Fittick's Road in line of Sewer. 1 = Boulder-clay. 2 = Sand and Gravel. 3 = Rock. Horizontal Scale, 6" = 1 Mile. Vertical Scale, 1" = 20'.

and presently began to cut their way through solid rock. Consequently they are now found winding here between steep banks of boulder-clay, there through a gorge excavated in solid rock, in other places where the glacial detritus has yielded more readily, meandering through broad alluvial flats.

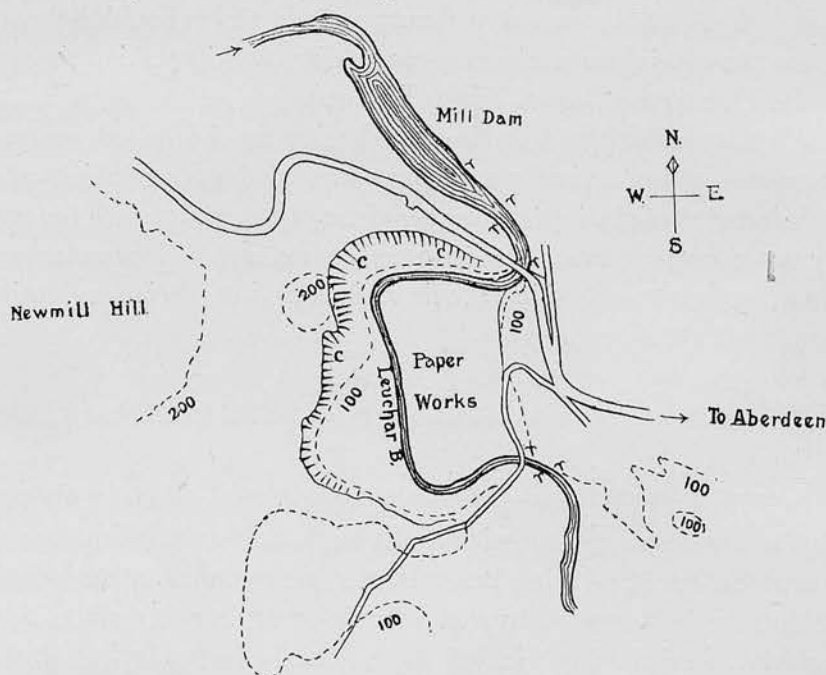
A very fine example of this diversion of streams is seen in the Leuchar Burn above and below the Paper Mills at Culter.

At and above the Bridge of Culter, the burn cuts its way through solid rock. Below the bridge it makes a sweep to the westward along a bend carved out of boulder-clay. Below the mills it again enters a rock-gorge. At both gorges the surface of the rock is clearly seen to be dipping west below the superficial accumulations (Map 4; Fig. 11).

The explanation seems to be that the pre-glacial valley lay to the west of that of the present stream, and was filled up by a tail of boulder-clay that accumulated in the rear of Newmill Hill as the ice streamed eastwards. The post-glacial burn in making its way towards the Dee

has been diverted; and at the two points mentioned, has been compelled to erode a channel for itself through solid rock.

To a similar cause is to be attributed the diversion of the Burn of Dess and in part at least the origin of the Loch of Auchlossan. The



MAP 4.—Sketch-Map of Leuchar Burn near Culter. *r, r, r* = Rock. *c, c, c* = Boulder-clay.



FIG. 11.—Diagrammatic Section across Leuchar Burn at Bridge of Culter.

rounded hill of Cnoc Dubh to the south-east of Mortlich tails off into the long ridge of the Muir of Dess which terminates against the hill-side above the Bridge of Dess. The composition of this ridge has been revealed partly by the stream, partly by the tunnel constructed by Mr. Barclay to drain the loch. This, down to a point close to the

waterfall, was driven through boulder-clay. Dammed back by the ridge, the drainage of the circle of hills bounding the Lumphanan Basin formed the Loch of Auchlossan.

The overflow from this sheet of water passed over the east end of the boulder-clay ridge close under the hill behind Desswood House. Had the outflowing stream encountered nothing but boulder-clay, the loch would have been drained naturally long ago. High terraces at Bogloch and south of the farm of Auchlossan prove that once it was much more extensive than any historical record shows. But after cutting down some distance through boulder-clay, the stream encountered a ridge of rock which, since it rose considerably above the bottom of the loch, had to be removed before the water could be entirely drawn off. The little gorge above the waterfall shows that this has been partly accomplished.

Down-stream from the rock only glacial deposits had to be attacked. These have yielded more readily, with the usual result—the formation of a waterfall. This waterfall at Slog of Dess, about 15 feet in height, is one of the beauty spots of Middle Deeside.

In pre-glacial times the drainage of the Lumphanan Basin must have entered the Dee to the west of its present point of entry unless the hollow formerly occupied by the Loch of Auchlossan is entirely due to glacial erosion, which, considering all the facts of the case, seems unlikely.

Just below Bridge of Coull a long sow-backed ridge or drum of glacial detritus, breached by the Tarland Burn, stretches westward for a considerable distance. Its length corresponds with the direction of the ice-movement as shown by *roches moutonnées* near by.

This seems to be the barrier,¹ lowered no doubt by denudation, that held up the loch which once occupied the bottom of the hollow between Coull and Tarland. Within recent times there existed here a marsh—Bog More—which has been drained and brought under tillage. The terraced flats that fringe the hollow are lake terraces marking

¹ The lowest point on this barrier is some feet higher than the surface of the ground at the Bridge of Tarland.

stages in the draining of this post-glacial lake. The barrier has been gradually cut down by the Tarland Burn.



Photo by J. Mathieson.

VIEW L.—Waterfall at Slog of Dess.

The whole valley of the Tarland Burn, indeed, from Coull to Balnagowan seems to have been blocked by glacial detritus piled up between Balnagowan Hill and the flanks of Mortlich.

The pedestrian and still more the cyclist who passes northward from the Dee at any point between Banchory and Park can hardly fail to be struck by the switchback nature of the roads. Ridges with intervening hollows run approximately east and west.

The ridges seem to be in part tails of boulder-clay in the rear of projecting knolls of rock, in part the usual drums of that material. On the other hand, the hollows may be, and some of them certainly are, erosion hollows, though the paucity of good sections precludes dogmatizing.

It is at all events clear that the trend of hollows and ridges here

bears a definite relation to the ice-movement as shown by the ice-worn rock at Leys of Crathes.

A similar parallelism of minor surface-features and coincidence of their length with the direction of ice-movement is noticeable about Tarland and Logie-Coldstone and northward towards the base of Sockaugh and Broomhill.

4. *Moraines*.—When the ice was stationary, whether in advance or retreat, there would be piled up terminal moraines formed of the rubbish shot over its front, extruded from beneath it, or derived from the melting of its dirty lower layers. If the ice were advancing, these moraines would be incorporated in its bottom-moraine as it moved forward: if it were in retreat, they would be left as hummocky mounds and ridges.

In front of terminal moraines sheets of sand and gravel are spread out by the water derived from the melting of the ice. These fluvio-glacial deposits—"overwash deposits"—will be concentrated along the valley-bottoms forming "valley-trains".

While a glacier or ice-sheet is continuously retreating no terminal moraines are formed: only boulder-clay and sands and gravels will remain to mark the retreat.

By terminal moraines the former extension of glaciers and ice-sheets can be determined. The outermost moraines mark the farthest limits reached: pauses in the retreat are marked by the others. The outermost or true terminal moraines of the Scottish ice-sheet lie beneath the sea.

But in addition to terminal moraines glaciers leave lateral moraines behind them. The lateral moraines generally found in this country are not the piles of angular rubbish with which pictures or diagrams of Alpine glaciers in text-books have made us familiar. Along both sides of a glacier, particularly near its termination, there flow streams of water. By these the rubbish lodged at the edge of the ice or between the ice and the valley-wall is washed and sorted. If the glacier stands for a long time at the same level against the valley-wall, it may even happen that the solid rock abutting on the ice is cut into

by these lateral streams; while the whole of the lateral moraine may be levelled so as to produce a terrace which—on the surface at any rate—will exhibit stratification¹ (Figs. 12 and 12 (D)).

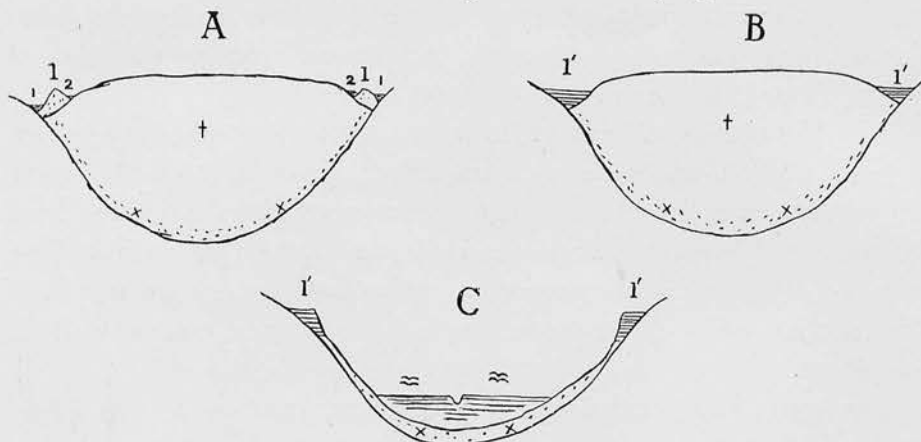


FIG. 12.—Diagram Showing Method of Formation of Stratified Lateral Moraine.

1, 2 = "Paraglacial" Streams.

1 = Ordinary Lateral Moraines (A).

1' = Stratified Lateral Moraines (B, C).

† = Ice.

× = Ground Moraine and Dirty Ice (A, B).

× = Boulder Clay (C).

≈ = Overwash Deposits and Post-Glacial River Alluvium.

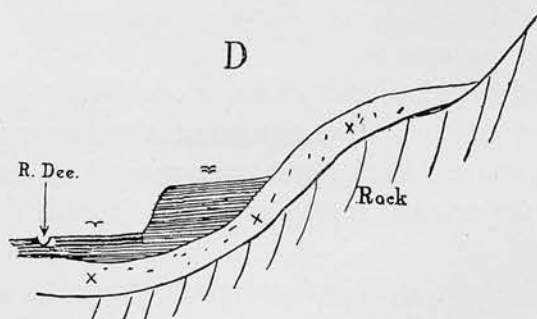


FIG. 12 (D).—Diagrammatic Section of North Valley-wall of R. Dee at Bieldside. The Rock is covered with Boulder-clay (×); on the Surface of the Highest Part of the Boulder-clay there is much Water-worn Gravel and Sand. (See p. 45.)

≈ = Fluvio-glacial Gravels (Overwash Deposits) (?).

≈ = Recent River Terrace.

The ridges near Loch of Loirston, on Tullos Hill, near Corbie Loch and farther north are moraines of retreat. Just above Murtle

¹Prof. H. C. Lewis, *Glacial Geology of England and Wales*; Dr. T. F. Jamieson, *Quarterly Journ. Geol. Soc.*, 1874.

much-denuded hummocks on both sides of the river may mark another pause in the recession of the ice.

From the east end of the Loch of Park there runs towards the Dee a hollow partially choked with glacial debris which from its hummocky surface is probably morainic in character. This hollow forms the natural outlet of the burn that enters the west end of the loch. The surplus waters of the loch, however, pass first westward and finally southward into the Dee by two outlets.

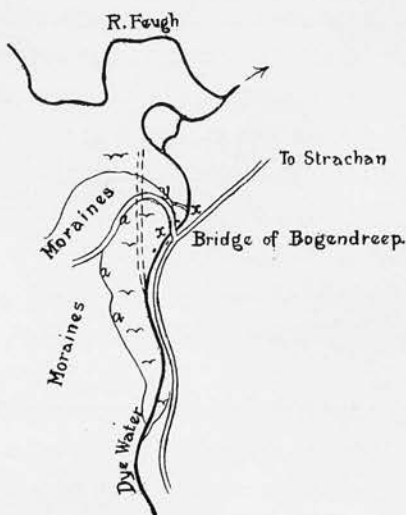
That the drainage is abnormal is perfectly clear. It has been reversed by the morainic dam at the eastern end of the loch. The loch is shrinking slowly, doubtless because the outgoing stream has so slight a fall and so sluggish a current that its erosive power is very small. The course of the stream has in fact been so "corrected" that it is for a considerable distance little more than an open drain.

At the eastern end of the Strachan Valley (near Mill of Cummie, Gellan and Blackness) and at the junction of the Feugh and Dye, other moraines of retreat may be noted. At the latter point the mounds are remarkable for their profusion and size—some are at least 100 feet in height.

To the moraines near Gellan reference will be made later. Those at the junction of the Feugh and Dye have evidently been laid down in the angle between the ice that during the retreat of the ice-sheet occupied the Strachan Valley and that which filled the valley of the Dye. The materials composing them are water-worn, doubtless by the streams of water that coursed over, alongside of, or under the dissolving ice. Numbers of stones can be picked up that are foreign to the basin of the Feugh and its tributaries. This is true also of the moraines at Gellan. Neither set can be due simply to glaciers descending the Feugh, Aven, and Dye. Ice-markings on the ridge between White-stone and Potarch show that at one period ice streamed from the north-west into the Strachan Valley. This ice brought with it the serpentine, greenstone and quartzite found in the moraines.¹

¹ Non-granitic boulders are not confined to the moraines on the north side of the valley as stated by Dr. Jamieson (*Quart. Jour. Geol. Soc.*, 1874).

At Bridge of Bogendreep the Dye water before entering the open valley of the Feugh passes through a typical rock-gorge, with vertical sides, cut in granite. To the west for a mile or more the ground is occupied by the gravelly moraines mentioned above. A gap in these, fifty yards or so from the gorge, is distinctly lower in level than the top of the rock through which the stream has cut its way. On one side of this gap is an alluvial terrace a few feet above the present level of the Dye, on the other the alluvial flats of the Feugh and Dye. No rock is exposed except at and close to the gorge. The erosion of the



MAP 5.—Sketch Map of Junction of Dye and Feugh.

~~~~~ = Alluvial Flats of Dye and Feugh.

~~~~~ = Alluvial Flat of Dye.

glacial deposits on both sides of the ridge at *y* (Map 5) makes it perfectly clear that no rock occurs at this point unless at a level considerably below the top of the rock at the gorge, where its surface is seen to be dipping westwards at a high angle below the alluvium and moraine. This is as clear a case of post-glacial diversion of a stream as one can expect to find anywhere (Fig. 13).

The Dye originally flowed in the direction of the dotted lines (Map 5): its valley was blocked by morainic material deposited as stated above. When it again began to flow after the retreat of the

ice, its waters sought the lowest level, which here lay over a spur of rock projecting from its eastern valley-wall. Quickly eroding a

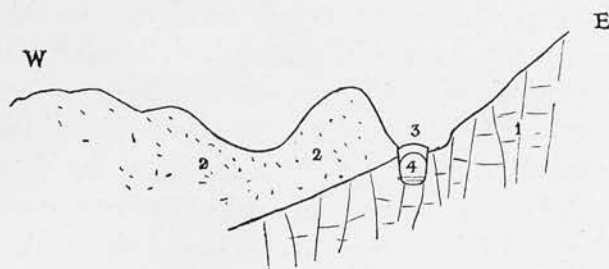


FIG. 13.—Diagrammatic Section across the Dye at Bridge of Bogendreep.
1 = Rock (Granite). 2 = Moraine. 3 = Bridge. 4 = Dye.

channel through the glacial deposits, it by-and-by encountered the solid rock into which it also cut. But in the solid rock vertical erosion would proceed slowly and this would check vertical erosion higher up. Consequently the stream above *xx* would meander and expend its energy in cutting into its banks. The alluvial terrace (*~*) is the result.

How near the stream came to deserting the rock-gorge may be judged from the narrowness of the ridge at *y*. The stream once coursed along the line *a a a*. Had a little more time been allowed it and the river-curve become a little more accentuated, the Dye would have pretty nearly resumed its pre-glacial course. With the cutting down of the rock (*xx*), however, the fall of the stream was increased and its course above the gorge became straighter. The ridge, *y*, was spared and the river assumed its present track.

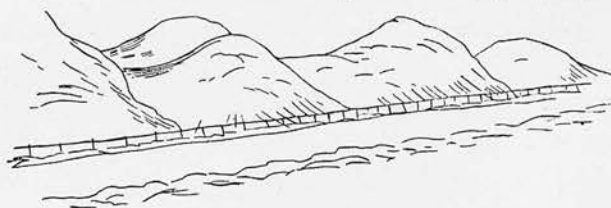
A beautiful semicircular moraine curves round the mouth of the Aven where it debouches on the Strachan Basin.

Two similar lines of moraine circle round the mouth of the narrow valley of the Upper Feugh: one extends from Drumhead Free Church to the opposite side of the valley by Mill of Clenter; another—less perfect—lies a mile or so higher up. The materials of both, so far as I have seen, are purely local.

Above the lower of these is an alluvial flat little eroded by the stream, evidently the site of a vanished lake—a portion of it still exists—dammed by the moraine, and now drained through the cutting

down of its barrier by the Feugh. Below the moraine is a wide spread of gravel and sand—a typical “overwash deposit”.

From Cambus o' May to Tullich on the north side of the Dee the angle between the flanks of Culblean and the Cnoc Dubh ridge is filled with moraines from 650 feet up to nearly 1,000 feet above sea-level. Similar moraines extend up the south side of the river from the neighbourhood of Dinnet nearly to Pananich, but do not reach so high a level. They are very conspicuous near Deecastle and opposite Cambus o' May and Dinnet Stations (obscured by trees).



Moraines, Mosside, Strachan.



Moraine, Mill of Clenter, Feughside.

VIEW M.

Here, too, occur the best examples of undoubted lateral moraines to be found on Deeside. That on the north side of the river will be referred to later; that on the south side stands at a level about 200 feet lower than the other. Both are of the degraded type already referred to (p. 37 and Fig. 12), and form gently sloping terraces dotted with erratic blocks. The southern moraine extends from Brackley down to Pananich as a well-marked high-level terrace. Where it is exposed in sections it is seen to consist of imperfectly rounded stones

and clayey sand. Similar terraces are noticeable near Glenmuick House.



VIEW N.—View from Cnoc Dubh looking W., Craigendarroch in middle distance, Moraines in foreground. *a, a* = Northern Lateral Moraine. The Conical Hillock is situated where the Queel Burn crosses the Moraine. *b, b* = Southern Lateral Moraine near Ballater.



VIEW O.—Lochan, dammed by a Moraine, high up on Western Face of Cnoc Dubh.

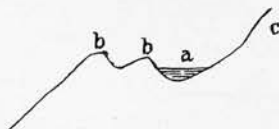


Diagram Illustrating the Origin of the Lochan on Cnoc Dubh.
a = Lochan. *b, b* = Moraine. *c* = Side of Hill.

The lower part of Glen Muick about Birkhall is dotted with moraines, relics of the vanished glacier of the Muick. The degraded moraines at the east end of Loch Muick have been mentioned (p. 24).

As an easily accessible locality where moraines of the later phases of the Ice Age may be studied, we may mention the hollow between



Photo by J. Mathieson.

VIEW P.—Gap in one of the Moraines between Tullich and Cambus o' May. The old Tarland-and-Ballater Road runs through the Gap.

Conachcraig and Meall Gorm, three-quarters of a mile above Inschbobart on the road from Glen Muick to Balmoral. A semicircle of moraines encloses a boggy flat, a lochan in wet weather, above which tower the craggy slopes of Conachcraig.

Of the moraines of the Derry and Lui, and of the corries of Lochnagar and the Cairngorms, there is little need to write. They are conspicuous for their size and so fresh in appearance that the ice might have retired from them but yesterday.

One other group we may mention—the group of beautiful conical moraines between Loch Builg and the Gairn. They form the barrier that holds up the loch, and dotted amongst them are many lochans. In very dry seasons the stream that issues from the north end of Loch Builg ceases to flow, and the surplus waters of the lake percolate through the substance of these moraines to the Gairn.

Without doubt terminal moraines add a touch of picturesqueness

to many an otherwise bare corner. The swelling ridges, steep-sided and rock-strewn, grouped irregularly yet with a certain order, rising abruptly from level ground or from the bottom of a valley and creeping up the hillsides, are sufficiently striking to attract the notice of even a casual observer.

Associated with every group of moraines that marks any considerable pause in the retreat of the ice, we have a frontal apron of overwash deposits, *e.g.*, below the moraines at Murtle, at Mill of Clenter, at Cambus o' May. From the latter place by Dinnet to Aboyne stretches the finest spread of gravels in the whole valley.

Besides those already mentioned, a close examination of the Dee Valley reveals other more or less clearly defined high-level terraces, which from their elevation above the stream must be of the nature of lateral moraines.¹ In the case of terraces at lower levels it must always be a matter of doubt whether they are of a similar nature or are the remnants, not yet removed by the action of the river, of the sheets of gravel and sand swept down the valley from the front of the retreating ice. To what depth these fluvio-glacial gravels filled the valley and at what level the post-glacial streams began to work, we do not know.

5. *Kames*.—Curious winding ridges of sand and gravel, on the tops of which erratic blocks are often perched, form conspicuous features in many parts of Scotland, *e.g.*, near Kemnay. These are called kames in Scotland, eskers in Ireland, ösar in Scandinavia.

The origin of kames has long been a vexed question in geology, but the accepted theory now is that they are casts of sub-glacial, englacial, or possibly supra-glacial streams.²

While tails and drums of boulder-clay assumed their present form and position when the ice-sheets and glaciers were still in motion, kames belong to the period of dissolution when an amelioration of climate caused copious streams of water to pour under, in, or on

¹ See Sec. across Dee between Murtle and Bieldside (Fig. 12, D).

² *Sum. Prog. Geol. Surv.*, 1901, pp. 186-87. Gregory and Garwood, *Q. J. G. S.*, 1898.

the ice. Consequently, the latter do not bear the same definite relation to the direction of ice-movement as the former.

To the south and east of the Hill of Fare and extending up the low ground as far as Raemoir are mounds and winding ridges of sand and gravel. Most, where opened, exhibit distinct stratification, and in most, too, the stones are well water-worn, though striated stones are not uncommon. Along the south side of the Quartons Moss on the Gormack Burn, north-west of Drum Castle, they are particularly striking. They are probably kames rather than moraines.¹

The abrupt gravel ridges near the head of the Den of Murtle are doubtless kames. The similar ridges immediately behind Feughside Inn, Strachan, both in internal structure and outward shape, are suggestive of kames rather than moraines.²

6. *Overflow Channels and Glacial Lakes*.—One of the most curious effects of the Ice Age upon the natural features of the Dee Valley is the production of many strange and hitherto unnoticed and unexplained wind-gaps and deserted water-channels that cut across both the principal and secondary watersheds. Wherever a ridge runs transverse to the length of the valley (*i.e.* to the course of the ice) one or more of these is sure to be found; and in some cases the ridge bounding the Dee Basin as a whole has been similarly cut across.

Reference has already been made to the streams of water that course along both sides of a glacier near its termination. Where a spur projects from the valley-wall, the lateral stream on that side will either follow the edge of the ice where it abuts against this spur, or, if there be in the spur a col of suitable elevation, take the shorter route across the col and rejoin the ice farther down the valley. If the ice stand for some time at the level which just permits this to take place and then rapidly retreat and sink, little may remain to show that a stream has ever flowed over the col. If, however, the ice-level be

¹ *Mem. Geol. Surv.*, Explanation of Sheet 76.

² Dr. T. F. Jamieson (*Q. J. G. S.*, 1874) thinks them moraines. A good section is now (1906) exposed.

gradually lowered, the stream will cut down and down into the col so long as no new channel of escape at a lower level is opened to it.

Where the ice-front abuts against a ridge running transverse to the main valley, the schmelzwasser will flow partly down the main valley, partly across suitable cols in the ridge, and thus indirectly into the principal stream. As long as the water finds an escape across such a col a gorge will be eroded on the ice-free side of the ridge—a gorge which, if occupied by a stream after the retreat of the ice, shows signs of over-deepening, *i.e.* the stream is a misfit. For the volume of the existing stream depends on the drainage from its own basin, while the stream that excavated the gorge drew its supply partly, if not indeed mainly, from the water derived from the melting ice. Let the ice-level be lowered in such a way that the glacial stream can cut down into the col and we shall have a typical wind-gap formed, which after the dissolution of the ice very likely holds no stream at all.

At every point where the retreating ice of the Dee Valley has fulfilled these conditions, well-marked overflow channels remain. These channels may or may not now hold streams: and in either case they exhibit peculiarities which clearly show that existing streams are not entirely, if at all, responsible for their formation.

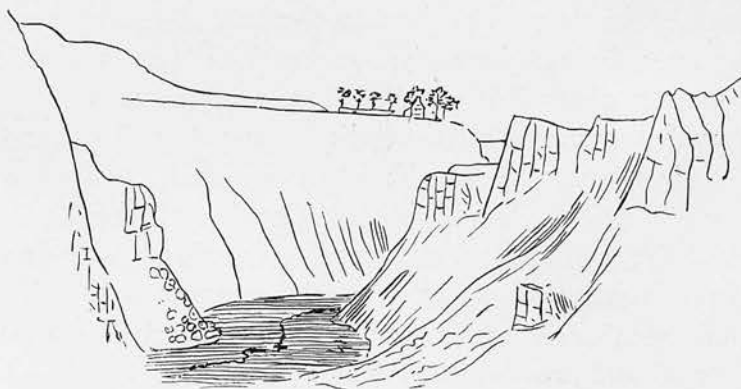
The cross ridge that separates the basins of the Feugh and Sheeoch exhibits overflow channels at two different levels.

At one stage in the dissolution of the ice-sheet the front of the ice filling the lower part of the basin of the Feugh rested against this ridge at an elevation of about 600 feet. It was continuous with ice that moved down the Dee and sent a lobe into the valley of the Sheeoch, which it blocked from below Wardend to Cairnballoch Wood. From Wardend to Garrol Hill the valley seems to have been ice-free (Map 6).

The schmelzwasser from the Feugh ice passed across the col between Garrol Hill and Shillofad, gradually eroding the deep gorge *in which the Garrol Burn has its source*—a gorge, 60 or 70 feet deep, cut in the Older Granite of the Cairnshee Magma, one of the hardest rocks in the district. Its sides are precipitous, its bottom

flat and marshy ; a mere dribble of water flows in its deepest part, and that originates in the boggy bottom higher up the gorge.

That the state of things here described really existed is tolerably clear. The sands and gravels swept over the col at the head of the Garrol Burn have formed a large stretch of high-level alluvial deposits extending from above Blairydrine to below Wardend, where they terminate abruptly. An excellent section of these deposits is exposed in a sandpit near Mill of Blairydrine, 360 feet above sea-level. Stratified sands and gravels becoming coarser towards the top point to the gradual filling up of a glacial lake held up by the ice dam lower down.



VIEW Q.—Sketch in the Gorge of the Garrol Burn.

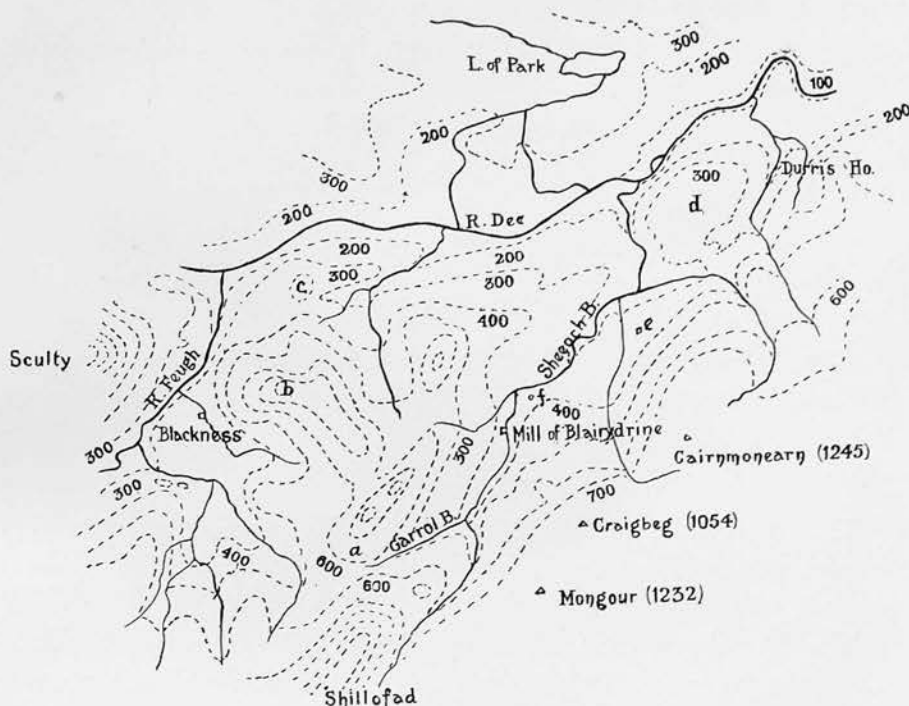
There are terraces which indicate 400 feet as the level of the surface of this lake. The abrupt termination of the gravelly deposits shows the position of the ice barrier.

It would appear that for some time the whole drainage of the Sheecho Valley passed close under the hillside south of Calladrum (where there is a curious little rock-gorge), along the hollow near Woodend School, and so by the glen at Durris House down to the Dee at Park. This glen is greatly "over-deepened".

The shrinkage of the ice caused the waters of the lake to sink so that there are gravel terraces at lower levels ; but, so long as the ice blocked the present outlet of the Sheecho into the Dee Valley, its surplus waters would flow past Woodend School and Durris House.

North of Mulloch Hill is a hollow in which lie many degraded

moraine mounds. This hollow has within recent times been partly occupied by a loch which drained by a considerable rock-gorge near Glenhead into the Sheeoch near Blairydrine. The gorge is too deep to have been cut by the outflow of a small loch, fed by no streams, and is a second overflow channel. Its intake at the west end of the hollow is at a slightly higher level than that of the Garrol overflow.



MAP 6.—Map of District S.E. of Banchory. Scale, $\frac{1}{2}$ " = 1 Mile.

a = Garrol Hill.

c = Maryfield Hill.

e = Calladrum.

b = Craig of Affrusk.

d = Cairnballoch Wood.

f = Wardend.

From the west end of the Garrol gorge down the valley towards Moss-side, Gellan, and Blackness the front of the gradually shrinking ice can be traced by a "spoor" of scattered moraines. But at a level of 400 feet or thereby, a pause again took place in the dissolution of the ice. The moraines about Gellan and Blackness rise to this height above ordnance datum. Along the western face of Craig of Affrusk for over a mile rests a flat-topped terrace, on the top of which runs the

lade that carries water from Blackness to the sawmill at Crofthead. A similar terrace fringes the west side of Maryfield Hill. Both are typical lateral (or termino-lateral) moraines, and both terminate in the gap south of Maryfield Hill. Through this gap runs an evidently water-worn channel, unoccupied by a stream, leading down to the Burn of Tilquhillie (Map 6 and Fig. 14).

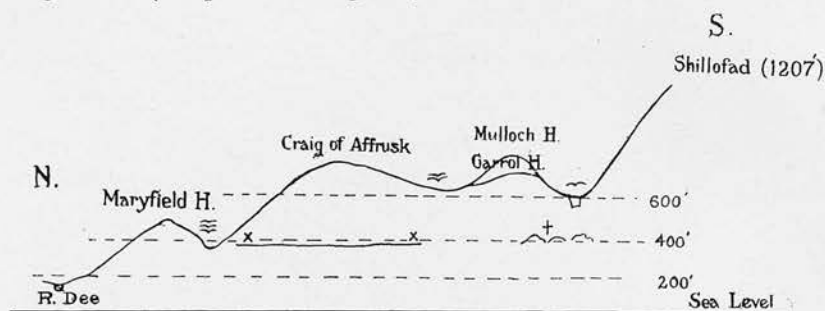


FIG. 14.—Diagrammatic Sec. from Shillofad to R. Dee showing position of overflow channels.

~ ~ ~ = overflow channels.
 x — x = Lateral Moraine.
 + = Terminal Moraines.

That the ice did not stand so long at the 400 feet as at the 600 feet level, is clear from the insignificant size of this overflow channel compared with that of the Garrol.

The Garrol gorge exhibits in perfection all the characteristics of an overflow channel. The distinctions between a normal valley and a glacial overflow channel may be tabulated as follows:—

Normal Valley.

- (1) The profile of the stream-line of a normal valley is a regular curve (see Diag., p. 8).
- (2) The valley is proportionate to the size of the stream occupying it.
- (3) The valley-walls exhibit the characteristic "curve of denudation"; and they are, in glaciated countries, generally coated with boulder-clay.

(4) The stream occupies the whole length of the valley and does not rise in a gorge.

Overflow Channel.

(1) The profile has a slight slope in its upper part near the "intake," a steeper slope lower down.

(2) The existing stream, if there be one, is a misfit, *i.e.*, is not proportionate to the size of the valley.

(3) The valley-walls are always steep, often precipitous, because being recent they have not been weathered back. They never show boulder-clay except where they have been cut out of it, as sometimes happens (see p. 59).

(4) The stream, if present, often rises within a gorge.

Of all the overflows within the basin of the Dee the most interesting, both from its magnitude and from the clearness of its causation, is that between Culblean and Cnoc Dubh, which cuts across the ridge separating the Ballater and Dinnet Basins. In order to make perfectly clear all the phenomena connected with this particular channel, reference must be made to certain peculiarities of the ground to the eastward.

The basin occupied by Loch Kinnord and the deep hollow running from the south-west corner of the loch towards the Deeside Railway are fringed by extensive high-level terraces. These have not the same elevation throughout. The materials composing them are coarse. There are no signs of terraces at lower levels: instead there are mounds and ridges of rudely water-worn material, or the high terraces drop abruptly to the level of the loch.

All these facts are inconsistent with the supposition that in Loch Kinnord we have the remnant of a once larger lake gradually drained by the removal of its retaining barrier. There is moreover no trace of such a barrier. They are consistent with but one supposition, namely, that the hollow in question was formerly occupied by a mass of ice left stranded during the retreat of the glaciers. The rubbish accumulating along the edges of this formed the terraces, while that borne in irregular

heaps on the ice or washed in below it gave to the basin resulting from its final disappearance its rough hummocky bottom.

After the glacier in the Ballater Basin sank below a certain level, it is certain that no ice could have surmounted the barrier at its east end. The portion of the glacier occupying the basin we are discussing would eventually be isolated, and would remain until its final dissolution in the condition of "dead ice";¹ and that too while an actively moving ice-stream might be following the present track of the Dee below Cambus o' May.

Along the steep hillside from a point above the quarries behind Tomnakiest to the col between Culblean and Cnoc Dubh over which passes the old road from Tarland to Ballater, runs a sloping terrace already mentioned (p. 42) and long ago noted by Dr. T. F. Jamieson as the lateral moraine of a glacier occupying the Ballater Basin.²

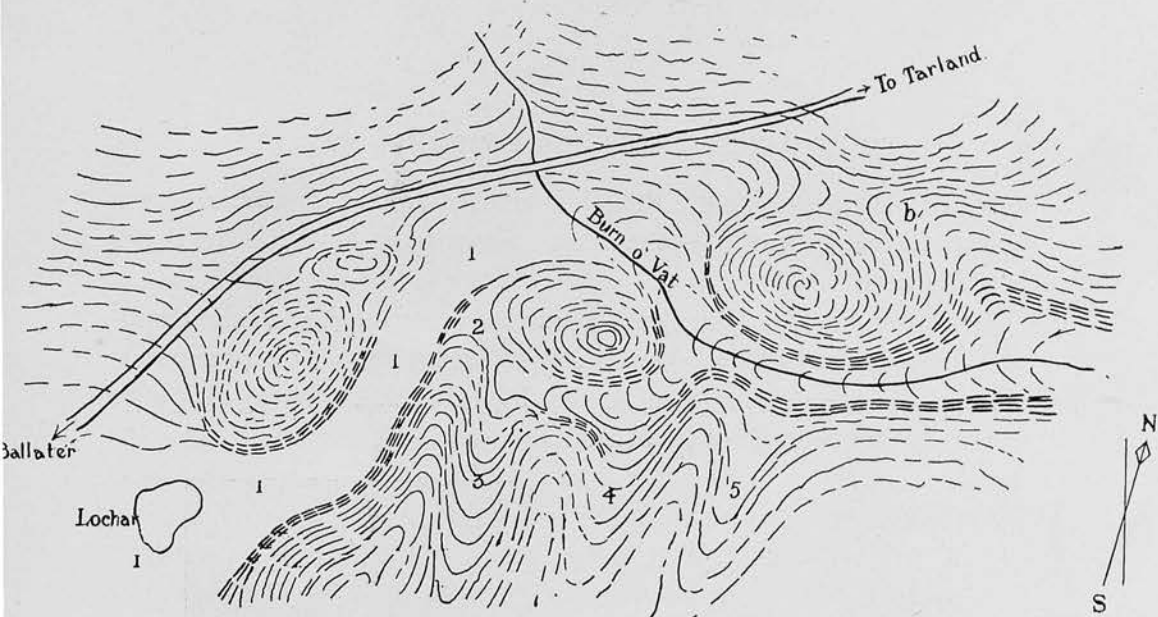
At its eastern end the moraine terminates in a typical wind-gap or dry gorge, cut across the col. This gap forms the commencement of the deep rock-gorgè (now occupied by the lower part of the Burn o' Vat) that extends down to and a little below the well-known "cave"—a distance of over half a mile. Upon the upper end of the gorge converge several water-worn channels, now dry (Map 7 and Sketches).

Evidently the water that levelled the lateral moraine flowed across the col and, reinforced no doubt by schmelzwasser flowing over the ice itself, eroded the whole of this gorge. The amount of erosion which the Burn o' Vat *per se* can effect is exhibited in the tiny groove traced on the hillside by that section of it above the col. What more effective eroding agent could there be than a copious stream of water descending with torrential velocity (300' in half a mile), and charged with such abundance of angular debris as it would wash out from the moraines of a glacier?

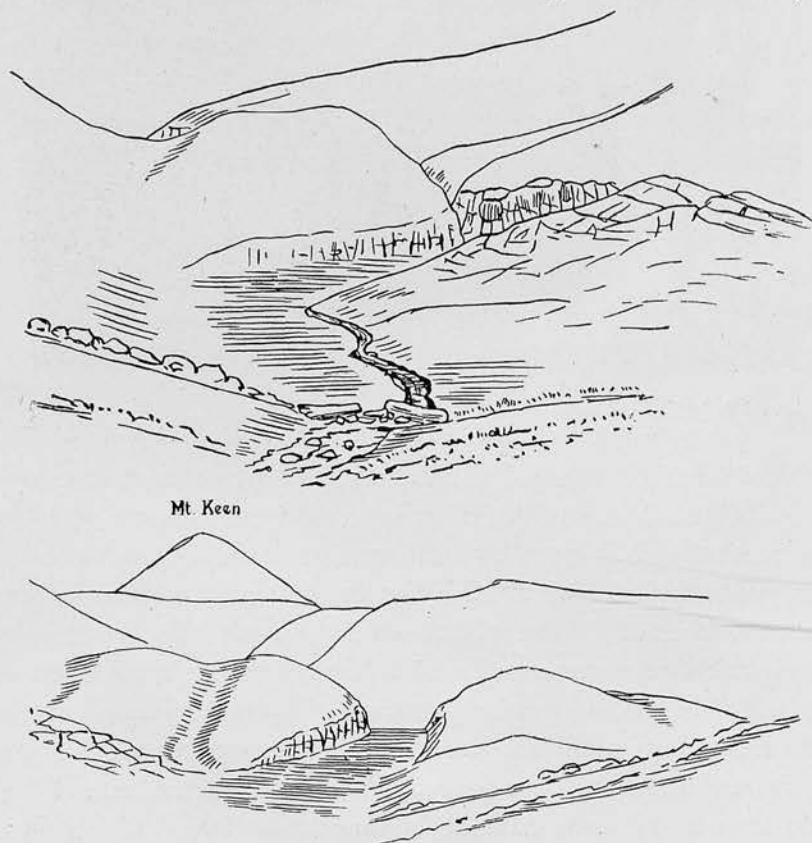
The size of this glacial stream is attested not only by the magnitude of the gorge itself but also by the size of the pot-hole, the so-called "cave," near Bogingore. This huge cauldron, quite half of which is

¹ Cp. Malaspina Glacier and other glaciers in Alaska, where dead ice is found supporting a growth of trees rooted in the rock rubbish covering its margin.

² It was recently found that this lateral moraine is not the highest deposited by the "Valley Glacier" of the Dee: a fragment of another is to be seen to the N.E. of the intake shown in Map 7. (See Supl. of Sheet 65. p. 123)



MAP 7.—Sketch-map of Intake of Overflow at Burn o' Vat. 1 = Main Intake now occupied by Lochan and Marsh. 2-6 = Intakes deserted before the Overflow finally settled into the Channel (1).



VIEW R.—Two Views of the Intakes shown in Map 7, sketched from the same Point. The Upper View shows the Point where the Burn o' Vat crosses the Road: in the Lower are seen the Main Intake (1) and the Earlier Intakes (3, 4).

now filled up with granitic debris, is almost circular in outline with a horizontal diameter of about 60 feet. From 20 to 25 feet of its depth is still visible.

This gorge, like that at the head of the Garrol, has all the distinguishing marks of an overflow channel—the flat intake, the precipitous sides, the present stream a most palpable misfit and entering the gorge not at, but a little below, its head.

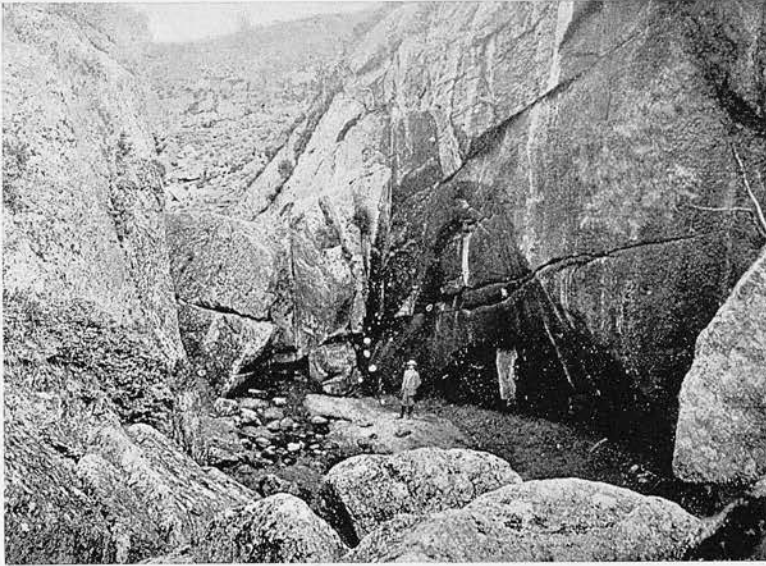


Photo by J. Mathieson.

VIEW S.—The "Vat" from the Top of the Cascade (right-hand side).

Now what became of the material swept down this channel? Had L. Kinnord existed at this time, one would expect it to have been practically obliterated by infilling, and would expect to find near Bogingore a typical *cone de dejection* or alluvial fan of large dimensions. Neither of these expectations is realised. Where the glacial stream, which, in order to erode so huge a gorge, must have been abundantly charged with debris, debouched upon flat ground we find a lake. Instead of an alluvial fan we have two terraces, sloping gently away from the mouth of the gorge. Where the central part of the fan should have been, there is a wide, hummocky-bottomed hollow through

which flows the present tiny stream. Has this missing portion been removed by denudation? Evidently the existing streamlet is incapable of having done so. Nor could the glacial stream have deposited the terraces and kept clear the hollow between, or afterwards eroded it out of the fan, so as to leave no traces of having done so. If, however, we imagine that the glacial Burn o' Vat was prevented from forming a perfect alluvial fan by the presence of a lobe of dead ice where its central part should have been, we have a theory that will account for all the phenomena, particularly for the existence of L. Kinnord.

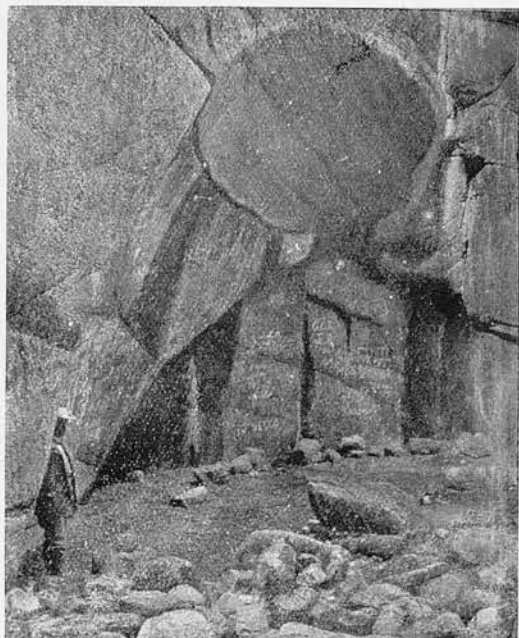
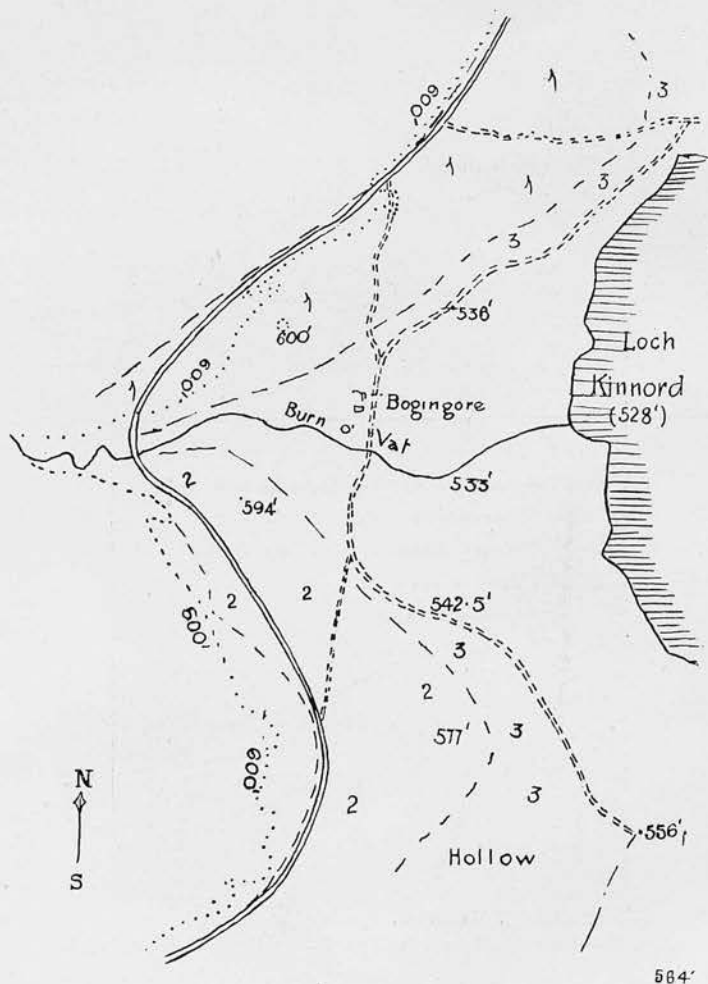


Photo by J. Mathieson.

VIEW T.—The "Vat" from the Top of the Cascade (left-hand side).

As this dead ice melted, its load of debris was left stranded as the irregular mounds (Map 8, 3). Along its margin to north-east and south-east the rubbish brought down by the glacial stream accumulated to form the terraces (1, 2 on Map). These have a distinct slope away from the mouth of the overflow, and are therefore not true lake terraces formed by an ice-dammed or other lake.

The ice in the Ballater Basin, after standing for a prolonged period at a level which permitted the formation of the overflow channel at Burn o' Vat, gradually sank, leaving moraines plastered at



MAP 8.—Mouth of Burn o' Vat and Loch Kinnord. Scale, 6" = 1 Mile.

different levels against the hillsides, till it abutted on the Cnoc Dubh ridge at an elevation of something under 800 feet. The schmelzwasser could no longer flow as before, but evidently turned southwards and passed over the end of the obstructing ridge just above

Cambus o' May House. From this point down almost to the road between Wisdomhow and Cambus o' May can be traced a small but very distinct rock-gorge, cut in ice-smoothed rock and partly filled

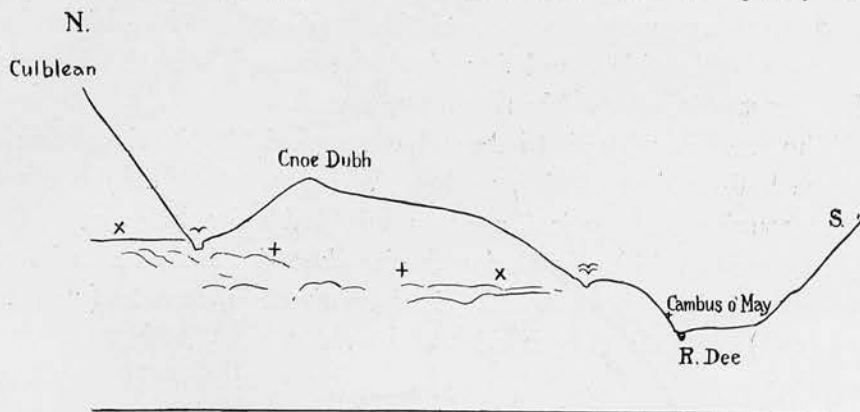


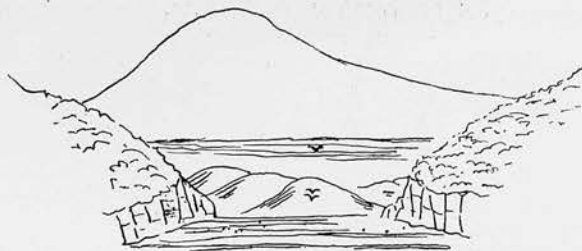
FIG. 15.—Diagrammatic Sec. from Culblean to R. Dee.

~ = Intake of Burn o' Vat.

≈ = Overflow channel to S. of Cnoc Dubh.

x = Lateral Moraine.

+ = Terminal Moraines.



Overflow Channel S. end of Cnoc Dubh Ridge.

~ = High Terrace on Ord Hill.

≈ = Kame.

VIEW U.

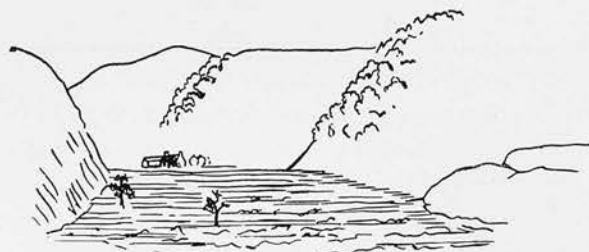
with a growth of peat. From its east end the direction of the gorge is continued by a typical kame, through which a cutting has been made for the road. This kame runs out into the hollow that extends from the railway, across the main road, as far as L. Kinnord. Its materials, coarse but well water-worn in the road-cutting, become pro-

gressively finer as it is followed to its termination in the above-mentioned hollow.

When it reached more level ground, the glacial stream that eroded the rock-gorge passed beneath the dead ice or cut its way through it between walls of ice, and deposited the materials of the kame in which a cast of its channel has been preserved.

The overflows described above have been dealt with first, because they are both typical and impressive. We shall now describe others which, though equally typical, are less remarkable for their size.

At one stage in its dissolution the ice-sheet (as before mentioned) made a pause just above Murtle Station, where hummocks ("gravel moraines") are seen on both sides of the river.



VIEW V.—Intake at head of Den of Murtle, looking N.W. towards Rotten of Gairn; Moss of Rotten in foreground.



VIEW W.—Intake at head of Den of Murtle, looking S.

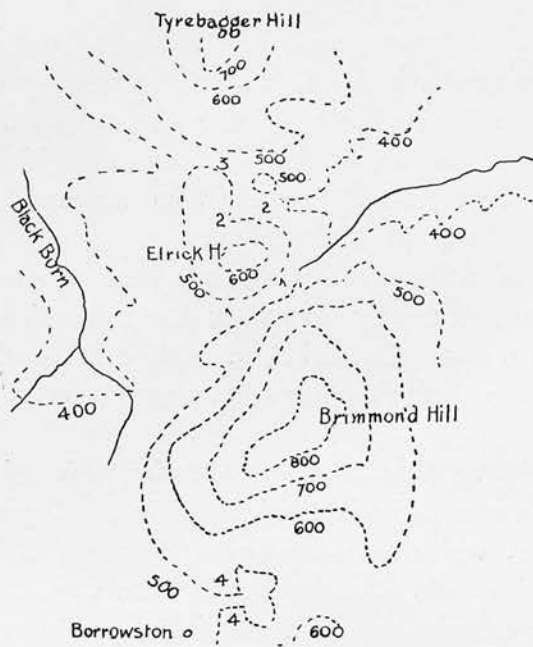
With the ice-front at this point in the immediate valley of the river, the ice covering the Skene district was doubtless thin and melting rapidly. The *schmelzwasser* could not follow the present drainage channel so long as the lower part of the Leuchar Burn about Culter was obstructed by ice. It evidently passed along the hollow of the Silver Burn north of Bean's Hill, by Rotten of Gairn and down the slope towards Murtle.

This overflow eroded the Den of Murtle, which is as typical an

overflow channel as one need look for. The level of the intake at Moss of Rotten (300') has been raised by a growth of peat.

The detritus swept down the Den has contributed to the great spread of high-level gravels between Murtle and Bieldside. These gravels are absent above the moraines at Murtle.

A quite typical overflow channel occurs between Elrick and Brimmond Hills at the 500 feet level. At the same level, also, a flat-topped moraine cut through by a stream is banked up against the hill-side near Borrowstoun, showing that for a time the ice stood at this elevation against the west side of the Brimmond Ridge (Map 9).



MAP 9.—Map of Overflow Channels in Brimmond-Tyrebagger Ridge.

1, 1 = Channel mentioned in Text. 4, 4 = Borrowstoun Moraine. 2, 3 = Undescribed Overflow Channels.

Very interesting, too, from its proximity to Aberdeen is the Dry Den near Hillhead of Pitfodels, which (as its name implies) is not due to any stream now flowing. It has carried the overflow of schmelzwasser across the ridge on which stands the high-level reservoir of the Aberdeen Waterworks. It is cut in boulder-clay.

At the head of the Temple Burn near Culter we have another easily accessible example of an overflow channel in the dry gap between Normandyke Hill (site of the Roman Camp) and Newmill Hill.

Near Lumphanan there occurs an overflow channel of very remarkable nature. Above Glenmillan House, on a level with the col over which passes the road from the Free Church to the Aberdeen and Tarland turnpike, is a curious triangular patch of sharp sand and gravel with its apex at the col. It is trenched across by a channel several yards deep and so narrow that one has some difficulty in not believing it to be artificial. The channel passes right across the col down into the basin of the Beltie Burn.

Evidently a miniature glacial lake had here been held up by the ice in the angle of the hills. It was obliterated by wash from the hillsides and from the ice itself. Finally as the ice sank the *schmelzwasser* cut a channel across its silted-up bed. This is the only sharply-cut overflow channel eroded in incoherent materials that I know of within the basin of the Dee.

The Pass of Ballater seems to have been an overflow channel, though its whole depth is by no means due to erosion by the glacial stream. The ice was embayed in the angle between Craigendarroch and the hills to the north: the *schmelzwasser* flowed eastward through the pass.

"An interesting case of diverted drainage is afforded by Glen Slugain. The upper part of this wide and deep valley contains a mere rivulet of water, which for considerable distances finds its way underneath quartzite scree. At the head of the glen a flat expanse of ground is covered with drift and morainic material reaching to the River Quoich, which makes a sharp turn to the westward at this point. It seems that what are now the head-waters of the Quoich used to flow down Glen Slugain, but that during the glaciation the ice descending from the plateau of Beinn a Bhuird ploughed out the wide east and west hollow to the south of that mountain, and with part of the removed material blocked the Slugain Valley. The waters of the Quoich were thus enabled to cut back along the hollow south of Beinn

a Bhuird and behead the Slugain Burn" (Mr. Cunningham-Craig in *Summary of Progress of the Geological Survey* for 1898, p. 173).

With the opinion that Glen Slugain affords an instance of diverted drainage I most cordially agree (see p. 19); to the date and cause of diversion assigned above there are serious objections, which may be stated as under.

(1) Quartzite *in situ* crops out at the very top of the Slugain, and continues to appear in close proximity to the streamlet for a considerable distance down the glen. Consequently the Slugain Valley is not blocked by glacial debris scoured out of the Quoich Valley or by any other.

(2) The Quoich Valley where it bends to the west and adjoins the head of the Slugain is itself partly blocked by morainic material brought down in late glacial times by the ice descending from the high corries of Beinn a Bhuird. This glacial debris extends to the col leading to the Slugain, but stops there (Map 10).

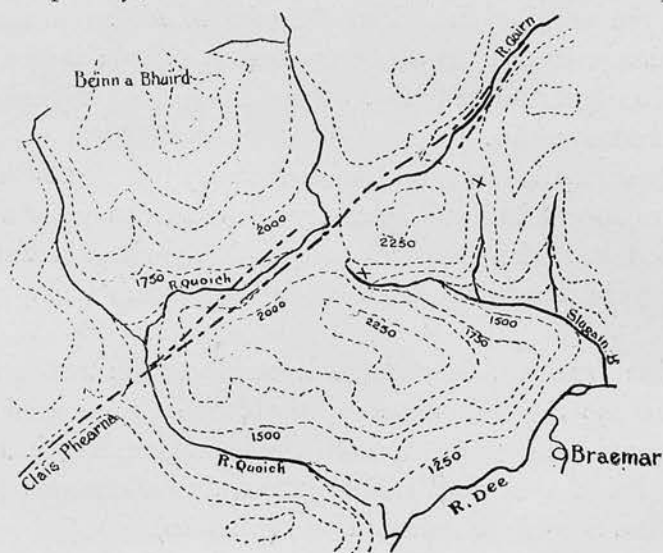
(3) Ice may widen and deepen a pre-existing hollow, but even extreme glacialists do not claim that it can plough out wide hollows, such as that occupied by the Quoich south of Beinn a Bhuird, where none existed before.

(4) The east-and-west portion of the Quoich occupies an extensive valley, which, even allowing for widening and deepening by glaciation, must be of considerable age. It is certainly older than post-glacial times, which would be the period of its origin on Mr. Cunningham-Craig's theory.

Ice-erosion might have lowered a previously-existing saddle between the Quoich and Slugain and so hastened the final diversion of the latter; but that the whole "wide east and west hollow south of Beinn a Bhuird" was "ploughed out" by ice is extremely unlikely. In pre-glacial times the Quoich had cut back almost, if not altogether, into the valley of the Slugain. Judging by the magnitude of the "wide east and west hollow," I most certainly think it had done so altogether (see section across Quoich, Fig. 16).

The Upper Slugain shows gorge within valley—the mark of a

rejuvenated not a recently beheaded stream. But the rejuvenation has been but temporary, for the stream is now a total misfit—it plays hide-



MAP. 10.—Map showing Basins of Slugain and Quoich.

- = Clais Fhearna Fault.
- - - = Contour Lines.
- ~~~~~ = Moraines.
- + = Portion of Slugain which gets lost under Scree.
- x = Probable Overflow Channel (not investigated).

Scale, $\frac{1}{2}$ " = 1 Mile.

Note.—The position of the Moraines is unfortunately not indicated on the Map, but can readily be made out by reference to the Text.

B.a Bhuid

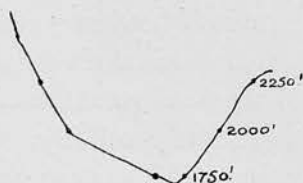


FIG. 16.—Section from Beinn a Bhuid S.E. to Carn na Drochaide, across R. Quoich.

Note.—The Sections in Figs. 16 and 16B start from the same point on Carn na Drochaide.

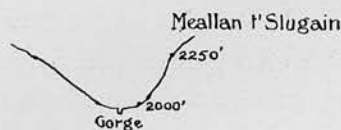


FIG. 16B.—Section from Carn na Drochaide towards N.E. across Slugain Burn.

and-seek among angular fallen blocks of quartzite. The rejuvenation and the formation of the gorge are attributable to the overflow from the glacier that left the moraines at and near the bend of the Quoich.

The valley—a very well-marked one—within which the above-mentioned gorge lies is the valley of the Slugain before its decapitation, modified no doubt by subsequent denudation and by glaciation (Fig 16B).

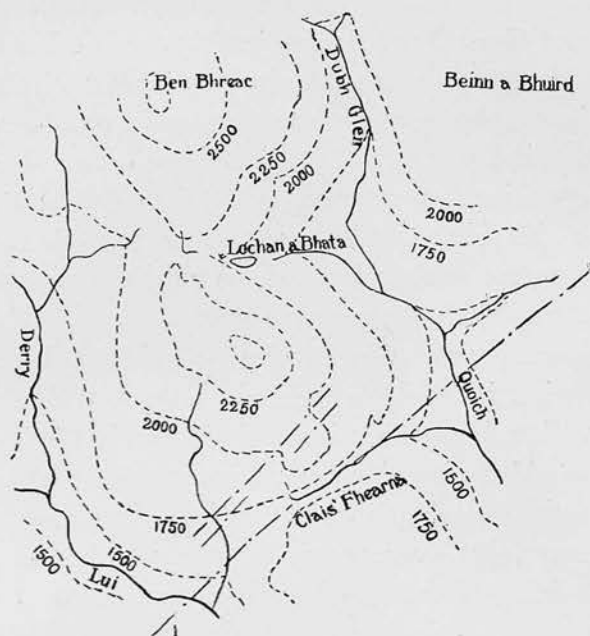
“At Lochan a Bhata, situated to the eastward of a col between Glen Dubh and Glen Derry, an interesting deposit has been formed. A flat triangular mass of coarse detritus contains the lochan, the apex terminating in a rocky gorge, while the base presents a very steep, scree-like face to the glen beneath. This deposit can only be accounted for on the supposition that the main glen (Glen Dubh) was filled by a glacier against the side of which, or more probably in a small glacial lake formed between the glacier and the hillside, the fan-like mass of material was deposited. The material forming the deposit was brought down by the small burn, which finally occupied and kept open the shallow depression in its delta which is now filled by the Lochan a Bhata” (Mr. Cunningham-Craig in *S. P. G. S.*, 1898, p. 173). To this it may be added that the surplus waters of the lochan issue from the bottom of the scree-like face of the fan. The loose nature of the materials through, not over, which the water makes its way has prevented the draining of the lake by the cutting down of the retaining barrier.



VIEW X.—View of the Lochan a Bhata Platform from the head of Glen Slugain, $3\frac{1}{2}$ miles to E. The platform is conspicuous as a triangular grassy patch on the brown heath-covered hillside. Above it is seen the notch cut by the overflow from Glen Derry; below it, the burn which carries off the seepage from the loch.

The description of the phenomena given above is accurate, but the latter part of the explanation can scarcely be considered satisfactory. For it does not appear how a burn can keep open even a shallow depression in its delta so as to form a lake. A more probable explanation of the existence of the lake is that the materials of the fan were partly

brought down by the burn and partly thrown off by the Dubh Glen glacier as lateral moraine, which, lying at the base of the fan, would form, even though partially levelled, a barrier sufficient to dam back the waters of the burn when the ice retired (Map 11).

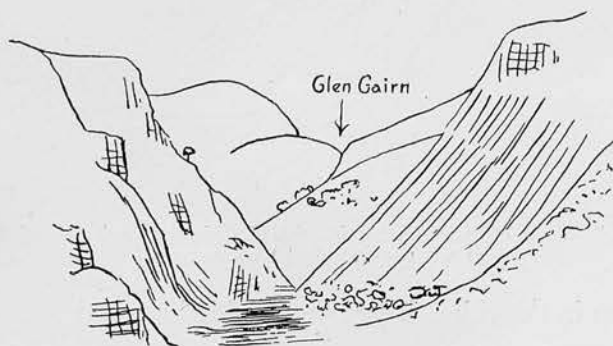


MAP 11.—Map of Lochan a Bhata and Clais Fhearna Overflows. I = Clais Fhearna Fault.

Further, the facts of the case are not fully stated by Mr. Craig. The burn that enters the head of the lochan is a tiny rivulet that loses itself again and again amongst the scree of its gorge: it is a misfit and could never have carved out the channel in which it lies. Clearly, the gorge is an overflow channel which has carried a glacial stream across the col from the Glen Derry glacier. That the Derry glacier should stand at a higher level than the Dubh Glen glacier was to be expected, seeing that it was fed by the snow-fields and corries of Ben Muickdhui.

Additional proof of a difference in level between these two glaciers is furnished by a second overflow channel leading across the ridge between them—from Glen Lui into Glen Quoich—along the line of the Clais Fhearna Fault.

The crushing and shattering of the rocks near this great dislocation would naturally render it a line of weakness, so that the ordinary processes of weathering would probably have produced a hollow along the belt of fracture. That weathering alone could not have originated the "Clais" is perfectly clear from the fact that it is now in process of being obliterated by scree from its rocky and in some parts precipitous sides. That it could not have originated under the present conditions of drainage is equally clear, for the tiny streamlet that trickles eastwards through it is at many points buried under coarse scree or dammed into miniature lakes by the finer materials shot down from the northern cliffs.

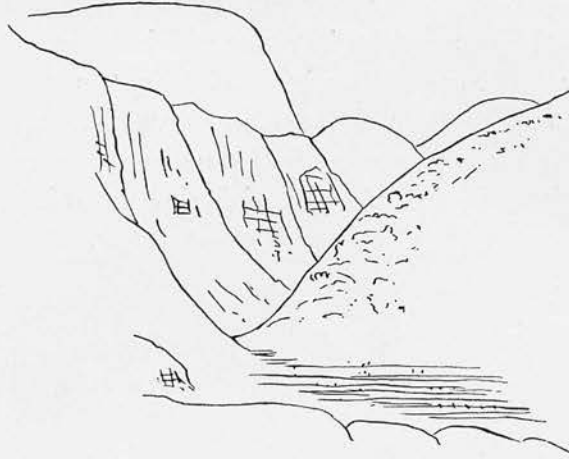


VIEW Y.—View in Clais Fhearna, looking E.

At its western end the Clais expands considerably. Here its bottom is occupied by a peaty flat with a lochan and by some low morainic mounds from which the ground sinks rapidly towards the Lui. This flat is the intake of the overflow, and the mounds are lateral moraine thrown off by the western glacier (Derry-Lui) along its eastern margin.

Of other overflow channels within the basin of the Dee it is perhaps needless to write. All exhibit the same features. A list of the localities where those that merit a visit are to be seen, may, however, be given: Craignarb, between Raemoir and Glassel (three channels close together); den at summit of road between Torphins and Lumphanan (locally "Satan's Den"); south of Bandory, between Birse and Potarch; between Loch of Aboyne and Bridge of Dess; ridge

between Glen Gelder and Glen Girnock ; between Glen Girnock and Glen Muick (channel opens into Glen Muick half a mile above linn ; opening obscured by trees). The latter two require further investigation.

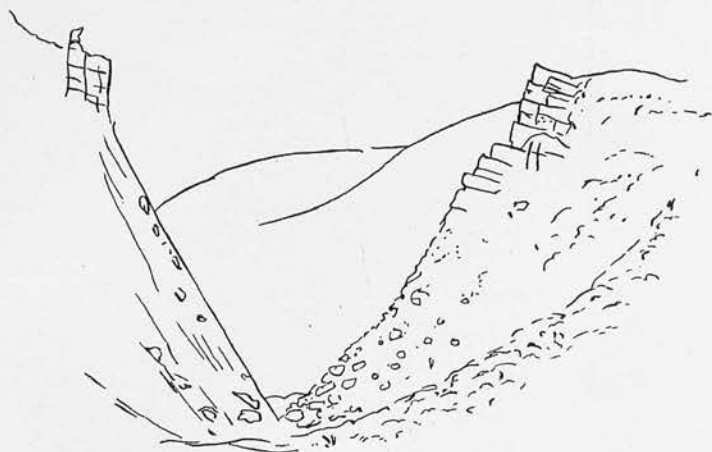


VIEW Z.—View of W. end of Clais Fhearna, Moraine Mounds and Lochan (partially obliterated by growth of marsh plants) in foreground.

The gap in the ridge between Clachnaben and Mount Shade, a prominent feature from many points on middle Deeside, and known as the “Devil’s Bite,” is clearly due to erosion by water. It lies on no line of fault or crush ; it cannot be due to weathering, by which, indeed, it is now being slowly obliterated (like Clais Fhearna) : it slopes from north to south, *i.e.*, towards the Dye. Probably it owes its origin to the *schmelzwasser* escaping from the ice on the north side of the Clachnaben Ridge towards the Dye Valley, in which the ice, being more exposed to the sun’s rays, stood at a lower level. Abundance of loose debris, morainic in character, is piled up just below the southern opening of the gorge.

The overflow channels that cut across the main watershed of the Dee Basin are, so far as I have observed, three in number. They are situated at the north lodge of Larny, at the Slack of Tillylodge, and at the head of Glenfinzie. They are interesting as proving what might have been expected from the position of the main ice-field of

the Eastern Grampians—that the ice-sheet lay thicker and persisted longer in the valley of the Dee than in the valley of the Don : all of



VIEW AA.—View in Gap between Clachnaben and Mount Shade, looking towards Glen Dye.

them lead from the former into the latter : all are rock-gorges of considerable size. At the western end of the first are indistinct terraces which indicate that it carried the drainage of a considerable glacial lake.

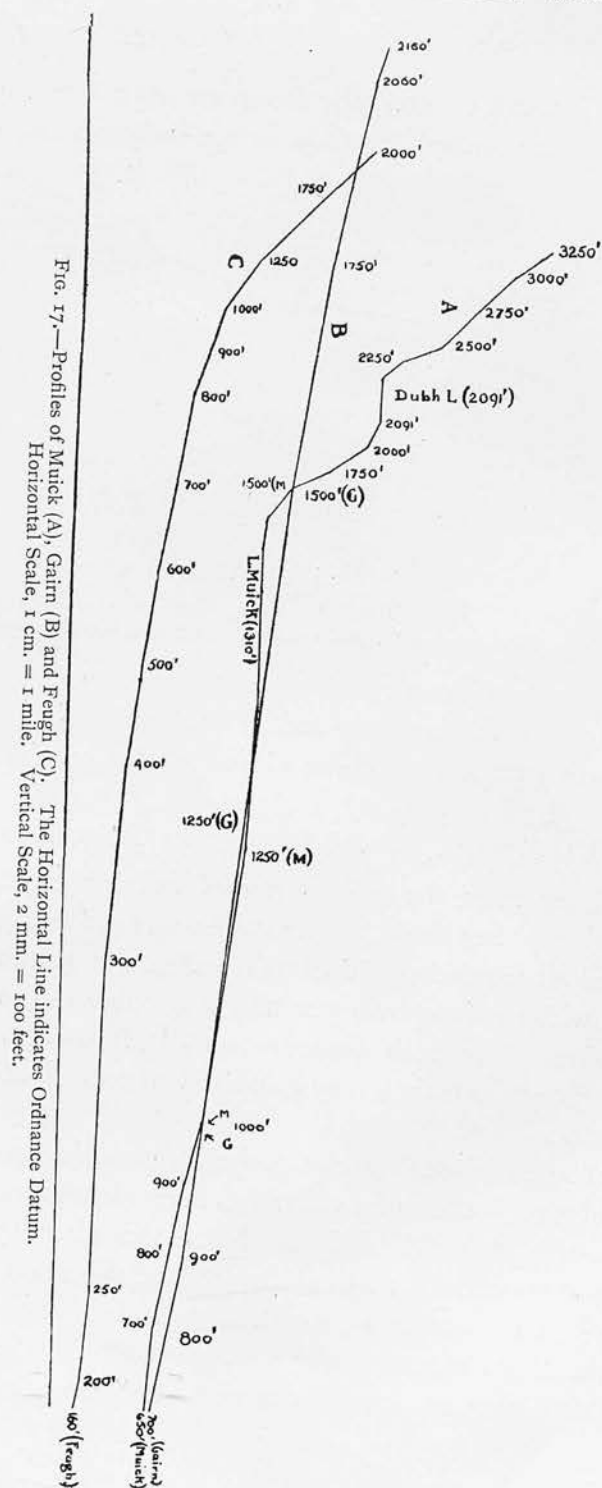
VI. SPECIAL POINTS REGARDING TRIBUTARIES.

In ordinary cases, the main stream of a drainage system possesses greater erosive power than its tributaries, and is therefore able to cut down its bed more rapidly. The main valley, too, generally coincided in direction with the ice-movement and was subjected to more severe glacial erosion. For both these reasons it is usual for tributaries where they enter the main valley to have a steeper gradient than they have higher up.

This is true of the tributaries of the Dee, and is especially marked where ice-erosion in the main valley has been most pronounced.

The profile of the Muick is worthy of study (Fig. 17). The great irregularities between the 1,250 and 1,500 and the 2,000 and 2,250 feet contours point to glacial erosion on a large scale, and the same feature is noticeable in the tributary which drains Loch Buidhe. The cross-sections of the valley at Loch Muick and Dubh Loch are characteristic

THE PHYSICAL GEOLOGY OF THE DEE VALLEY.



(Fig. 8, B). The extraordinary drop of the Glas Allt into the Loch Muick basin—1,000 feet in less than three-quarters of a mile—also points to a remarkable over-deepening of that hollow.

The profile of the Gairn, too, is most decidedly abnormal. The fall in the last mile is 100 feet, and this gradient is not again attained till we come near the source of the river. Owing to its direction, the whole extent of Glen Gairn from Gairnshiel upwards has been subjected to intense erosion during the time of the ice-sheet and also during the later glaciation when ice streamed into it from Ben Avon.

For comparison the profile of the Feugh has been plotted. It is almost normal with the exception of that portion of it between the 250 and 300 feet contours where the fall is very low (see p. 30). At the mouth there is the usual steep drop into the main valley.

A tributary stream descending with a steep gradient from a lateral valley brings with it a large amount of sediment. The main valley

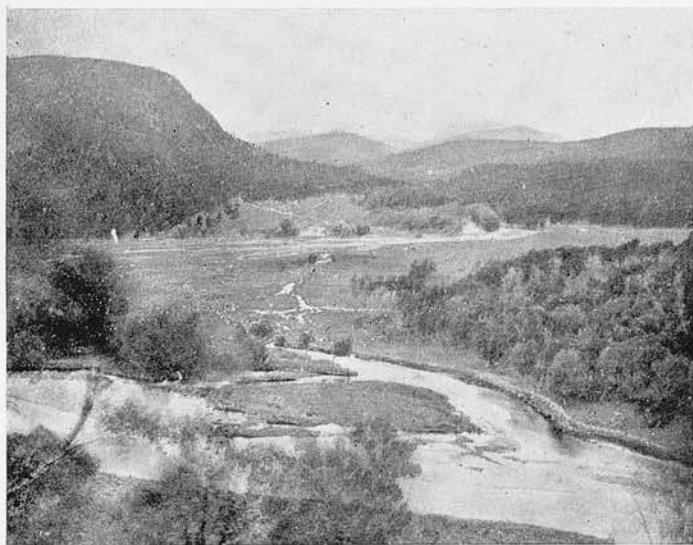
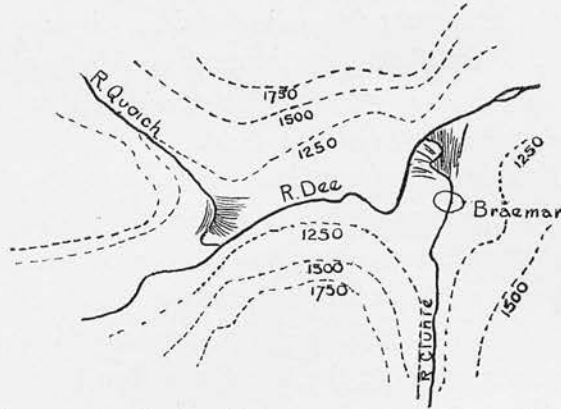


Photo by J. Mathieson.

VIEW BB.—The Alluvial Fan of the Quoich, the Dee in the foreground.

reached, the current is checked and the water-borne material tends to be deposited. The transported materials may, however, be carried

away by the main stream as fast as they are brought down. If not, they accumulate as an alluvial fan (or *cone de dejection*) which pushes



MAP 12.—Map showing Alluvial Fans of the Quoich and Clunie.

the main stream to the opposite side of its valley. Some very well-marked instances of this occur in the valley of the Dee.

1. The Quoich, descending impetuously from Beinn a Bhuid into the flat basin above Braemar brings with it in times of flood a heavy load of detritus which is spread out in an extensive alluvial fan. Over the surface of this it flows with divided and ever-changing course, splitting into branches as a great river does upon its delta. The presence of the fan forces the Dee to hug the base of the steep slopes that descend from Morrone (Map 12).

2. The fan of the Clunie at Braemar similarly pushes the Dee against its northern valley-wall (Map 12).

3. Another example of the same phenomenon is furnished by the Tullich Burn. The bed of this burn where it is crossed by the Aberdeen and Ballater turnpike is considerably higher than the ground to east and west. The cone is here largely composed of wash from the glacial deposits that once choked the burn a short distance to the north.

VII. RIVER TERRACES.¹

River terraces form conspicuous features in many parts of the Dee Valley, but there is little that is distinctive or remarkable about

¹The best account of river terraces and their origin is to be found in a paper by H. Miller in *Proceedings of Royal Physical Society of Edinburgh*, vol. vii. (1883).

them. Wherever the river has not been entirely engaged in vertical erosion of its bed, lateral erosion has been going on with the formation of terraces as a result. These are most conspicuous in the open reaches and where they have been carved out of fluvio-glacial deposits, *e.g.*, between Dinnet and Aboyne, at Crathes, etc.

One of the best localities for the study of terrace-formation is the Strachan Valley. Here terraces may be seen in all stages of formation and destruction. Two capital examples of severed spurs—the “Castle Hill” and another—may be seen between Strachan Church

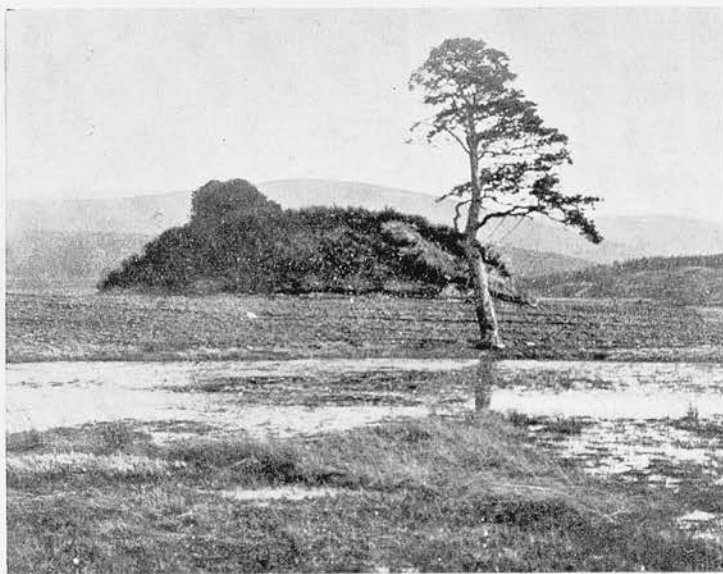


Photo by J. Mathieson.

VIEW CC.—The Castle Hill, Strachan—a Severed Spur.

and Whitestone Inn. Standing quite close together and rising about 30 feet above the present level of the Feugh, they are remnants of the extensive sheet of fluvio-glacial gravels and boulder-clay that once floored the whole valley from side to side. The manner in which such isolated knolls—real “mountains of circumdenudation” in miniature—are formed will be clear from the diagrams (Fig. 18, A, B).

The high terraces that fringe the valley up as far as Culter are

what have been called "Delta Terraces". They consist of materials spread out when the land was 100 feet to 135 feet lower than at present. When the land was elevated—and it probably rose for a time to a higher level than that at which it now stands—erosion of the delta deposits proceeded rapidly, but fragments remained.

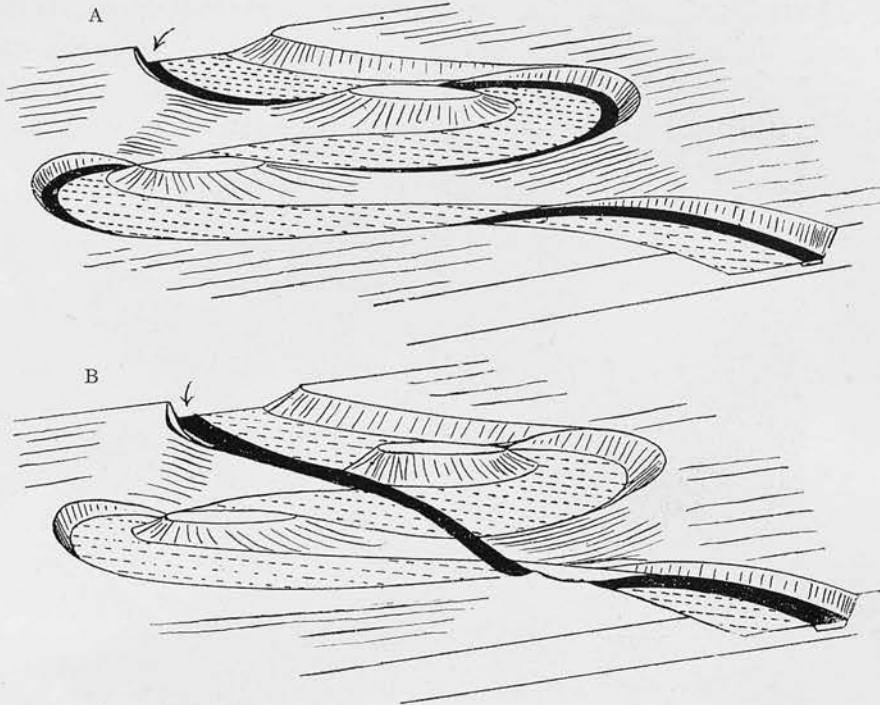


FIG. 18.—Diagrams Illustrating the Origin of Isolated Knolls standing on Alluvial River-flats.

At later periods the land stood successively at levels about 50 feet and 25 feet below existing ordnance datum. Whenever elevation took place, erosion proceeded apace, so that there are to be found delta terraces corresponding to, at any rate, the 100 feet and 50 feet raised beaches. But the river, finding lateral play, has removed much of them.

VIII. SCENIC EFFECTS DUE TO THE NATURE OF THE ROCKS.

The juxtaposition of hard and soft rocks in the valley of a stream gives rise to either (1) Waterfalls or (2) Close Gorge and Open Reach.

Waterfalls.—At *Linn of Muick* the water tumbles over a very hard, tough, gneissose rock: the pot-hole below the fall is excavated in a brittle well-foliated hornblende schist. The softer rock downstream is more readily eroded than the harder rock up-stream, and the usual result has followed.

The *Linn of Dee* is difficult to account for. At the present waterfall, if waterfall it can be called, we do not find hard and soft rocks in juxtaposition, so that the ordinary *raison d'être* does not apply. But just where the gorge below the linn opens out we find a small dyke, apparently of lamprophyre (I have not examined it microscopically), crossing the bed of the stream. On the south bank of the river it has been broken up and lies in huge detached masses. Immediately below the dyke the channel of the stream widens.

The lamprophyre offered much greater resistance to erosion and weathering than the adjoining rock, and the dyke at one time probably formed the lip of a waterfall. A pot-hole was excavated on its downstream side. Deprived of support by the removal of rock on that side, it would from its narrowness be readily broken down and the river would commence to cut its way back into the Moine Schists above.

Above the fall the river has, in fact, been rejuvenated, and in a comparatively short time, geologically speaking, will attain its regimen. The fall is being replaced by a gorge. By-and-by the sides of the gorge, weathering back, will assume the contour characteristic of an ordinary valley-wall.

The origin of waterfalls and rapids at the point of entry of tributaries has already been referred to (p. 67). The causes there assigned explain the falls of the Corriemuilzie Burn, Quoich and other streams; but the dykes of quartz-porphyry that cross the stream above the bridge partly—indeed mainly—account for the Falls of Feugh.

Close Gorge and Open Reach.—The narrow part of the valley of the Dee between Potarch and Banchory is an excellent example of close gorge. Above Kincardine o' Neil and below Banchory the valley widens. The constriction is plainly due to the hard quartzose rocks through which the river has had to cut its way in this part of its course.

At Bridge of Invercauld there is another very marked constriction due to the indurated (hornfelsed) schists that here cross the river.

But the best examples of close gorge and open reach are also cases of stream diversion, the gorge being cut in solid rock and the open reach showing nothing in its valley-walls more durable than boulder-clay (*vid. ant.*, pp. 33-34, 40-41).

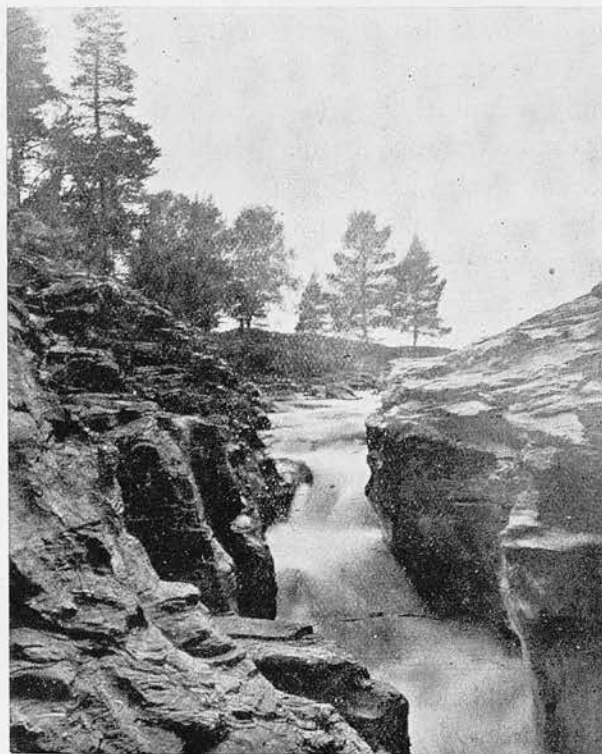


Photo by J. Mathieson.

VIEW DD.—The Linn of Dee from above the Bridge, looking up-stream.

At Craiglug we have a rock-gorge, in all likelihood post-glacial : above it is an open reach. What was the course of the river at this point in times immediately preceding the Ice Age is uncertain. A buried pre-glacial channel *may* exist to the north of Craiglug. That the Dee once entered the sea at Bay of Nigg is, however, in the highest degree probable. — Borings made before the recent work of

diversion was begun showed that the hollow from Craiginches to the Bay of Nigg was flooded by water-borne materials: rock at no point rose above sea-level,—none being met with in any of the bore-holes.¹

A precisely similar case occurs higher up the river. Below Bridge of Park the Dee sweeps through a deep channel cut in granite. To the south lies a wide flat, showing only gravel at the surface; and some parts of it are below the level of the top of the rock at the gorge. Above the gorge a fine open reach extends westward for miles.

It has been already pointed out that except in the more mountainous parts the effacing fingers of the Ice Age have removed most of the traces of the characteristic forms assumed by the rocks of Deeside under the action of the weather. Still the student of Nature will find plenty of interesting examples of rock-weathering wherever bare rock has been exposed for a sufficient length of time.

Granite.—The way in which granite weathers is well known. Round-backed ridges and rolling moorlands generally characterise its surface whether at high or low levels. In corries and where it is trenched by streams the regular system of joints traversing it, causes a steep face to be long maintained, just as in the case of a well-jointed and massively bedded sedimentary rock.

Any portion of a granite boss more resistant than the rest will tend to rise above the general level; and, if it yield equally on all sides to the action of the weather, will assume a conical shape. Mount Keen, a granite hill, is the most perfectly conical hill on Deeside—the granite is very closely jointed. The summits of Kerloch, Mount Battock and other hills also tend towards a conical outline. Ultimately the cone will weather down into a dome.

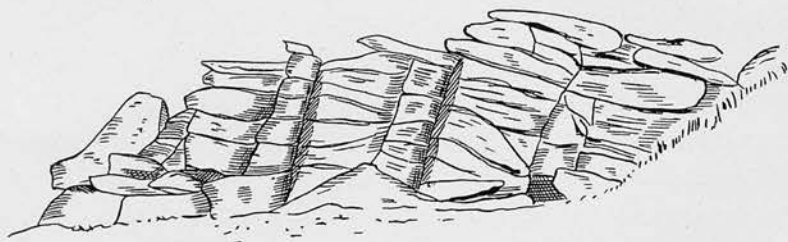
The typical corries, familiar to those who have scrambled among the Cairngorms, are, as previously stated, largely due to glaciation. The accumulations of scree at the base of their precipices are not being removed as fast as they are formed. By the continual growth of scree the lower parts of the precipices become protected from subaerial agents of denudation, and the weathering back of their upper parts finally

¹ The journal of these bores is, I understand, lost.

leads to the production of gentle slopes from which project here and there rounded weathered knobs of solid rock. In time these, too, disappear and the whole slope becomes covered with vegetation.

A good example of a decayed corrie, whose once precipitous sides are now reduced to comparatively easy slopes, may be seen on the north face of Mount Keen—the Corrach. The talus now forming at the base of the cliffs of Lochnagar indicates the ultimate fate of even this great corrie. But the strongly marked vertical jointing of the granite will long preserve a rim of cliff around its top. By the action of frost slice after slice will be detached from the face of the cliff and a vertical front maintained till the scree creep to the very top.

To the system of jointing in granite are attributable many picturesque effects of its weathering on a large as well as on a small scale. The sets of joints are three—one "horizontal," two "vertical," mutually at right angles. These joints are disposed with greater or less regularity. When best developed, they cause the rock to break up into cubical or cuboidal blocks. Weathering widens these natural lines of weakness, and a cliff face assumes the appearance of cyclopean masonry, *e.g.*, on Lochnagar.



Weathering of Granite, Corrie Etchachan.

VIEW EE.

The lines of joint thus opened out may be still further widened by running water. Their direction, in fact, may largely determine the courses of the streams. A very fine example of this on a small scale is seen in the gorge of the Burn o' Vat. This overflow channel pursues a curiously zigzag course, now following the one set of vertical planes of jointing and again the other, but in the main that which more

nearly coincided with the general direction of the glacial stream and which happened also to be the better developed. These joint planes are well seen at the "cave".

On a large scale the same phenomenon is probably exhibited by the streams that drain the Cairngorm Granite Area. Examination of



Photo by C. E. Campbell.

VIEW FF.—Jointing and Weathering of Granite, top of the Corrie, Lochnagar.

a map will show that in this district the valleys run north and south or east and west, *i.e.*, in what, as far as my observations enable me to say, are the prevalent directions of the "vertical" joints. The position of the corries also favours this view.

Another effect of the jointing is beautifully displayed in Glen Dee. Opposite the Devil's Point rises Carn a Mhaim. On its sides can be seen bare surfaces of granite, with well-marked joint planes which dip down into Glen Dee at a smaller angle than the side of the hill. The exposed slabs of rock resemble the tiles of a house-roof. In the Devil's Point the corresponding joint-planes have about the same dip,¹

¹ The other faces of the Devil's Point are determined by the sets of joints at right angles to that mentioned.

but in this case into the hill. The result is exactly the same as that produced by bedded rocks dipping across the valley of a stream. On that side on which the dip is towards the stream we find a gentle slope; on that side on which the dip is away from the stream there is a steeper slope or a precipice.



Photo by J. Mathieson.

VIEW GG.—The Devil's Point from below the Junction of the Dee and Geusachan.



Photo by C. E. Campbell.

VIEW HH.—The Devil's Point from the Glen Lui Footpath.

Viewed from certain points Cairn Toul and the Angel's Peak, particularly the latter, look like examples of escarpment and dip-slope. This seems to be due to the dip of the "horizontal" joints, but further detailed examination is necessary before any positive statement can be made.

The prominence of "horizontal" joints causes the granite near Cambus o' May to simulate a well-bedded sedimentary rock.



Photo by J. Mathieson.

VIEW KK.—The Peak of Cairntoul from the S.W.



Photo by J. Mathieson.

VIEW LL.—The Angel's Peak from the S.

In the case of a granite cliff the predominance of the one or the other set of vertical joints causes it to maintain a straight front or to advance and recede in buttresses and niches.

Quartz-Porphry.—This rock is not usually found in masses large enough to affect, except in details, the surface features of a country. It occurs chiefly in the form of dykes. One very resistant dyke of quartz-porphry causes the rapids at the Bridge of Potarch. The same dyke—or one in a line with it belonging to the same group—rises near Stranduff like a wall above the country rock.

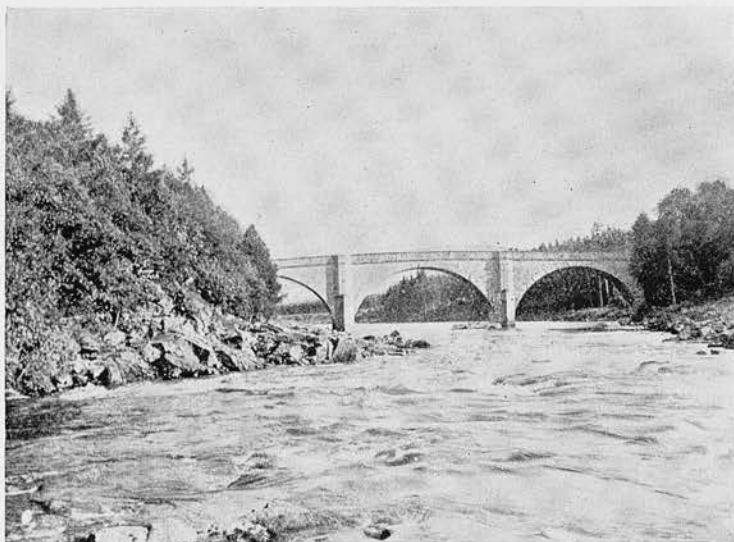


Photo by J. Mathieson.

VIEW MM.—The Rapids above the Bridge of Potarch. The Felsite Dyke is seen on both sides of the river.

Epidiorite ("Greenstone"), a basic igneous rock, is much more closely jointed than granite, and hills composed of it frequently assume the conical shape. Morven is the only conspicuous example on Dee-side.

Serpentine, though soft, does not readily yield to the weather. Hence serpentine areas are characterised by rough, knobby, irregular surfaces. The picturesque summits of the Coyles of Muick are monuments of the resistance offered by this rock to disintegration.

Quartzite.—Sir Archibald Geikie has pointed out the gracefully conical forms assumed by the quartzite mountains of the Scottish Highlands. Their distinctive outline is due to the uniform hardness

and close jointing of quartzite and to the way in which it consequently yields to the action of the weather. The majority of the summits in the basins of the Ey and Clunie are composed of quartzite and have the characteristic outline, *e.g.* the Cairnwell. From certain view-points, for example the hills above Loch Tilt, the two Ben Iutharns (or Uarns) are markedly conical. Ben-y-gloe is a very fine example, but it lies outside the basin of the Dee.

APPENDIX.

| | | | | | | | |
|----|-----------|--------------------|--------|----|--------------|----|-------------|
| 1. | <i>a.</i> | The Dee falls from | 4,000' | to | 2,000' | in | 2.37 miles. |
| | | " | " | " | 2,000' | " | 2.87 " |
| | | " | " | " | 1,750' | " | 2.87 " |
| | | " | " | " | 1,500' | " | 3.87 " |
| | | " | " | " | 1,250' | " | 11.75 " |
| | | " | " | " | 1,000' | " | 4.75 " |
| | | " | " | " | 900' | " | 3.75 " |
| | | " | " | " | 800' | " | 3.37 " |
| | | " | " | " | 700' | " | 4.5 " |
| | | " | " | " | 600' | " | 2.5 " |
| | | " | " | " | 500' | " | 7.5 " |
| | | " | " | " | 400' | " | 5.75 " |
| | | " | " | " | 300' | " | 6 " |
| | | " | " | " | 200' | " | 7.75 " |
| | | " | " | " | 100' | " | 15.5 " |
| | | | | | sea-level | " | 85.2 miles. |
| | | | | | Total Length | = | |

| | | | | | | |
|-----------|---------------------|--------|----|--------------|----|--------------|
| <i>b.</i> | The Spey falls from | 1,142' | to | 1,000' | in | 6.5 miles. |
| | " | " | " | 900' | " | 2.5 " |
| | " | " | " | 800' | " | 12 " |
| | " | " | " | 700' | " | 14.25 " |
| | " | " | " | 600' | " | 21.75 " |
| | " | " | " | 500' | " | 7 " |
| | " | " | " | 400' | " | 6 " |
| | " | " | " | 300' | " | 6.5 " |
| | " | " | " | 200' | " | 7 " |
| | " | " | " | 100' | " | 7 " |
| | " | " | " | sea-level | " | 6.25 " |
| | | | | Total Length | = | 96.75 miles. |

The figures for the Spey are taken from Mr. Hinxman's article in *Scot. Geog. Mag.*, 1901.

2. As the result of close examination of the district I am convinced that the moraines and other glacial deposits in the neighbourhood of Dinnet mark the limit of the valley-glaciation during Prof. Geikie's Fourth Glacial Stage (see "Great Ice Age," *Scot. Geog. Mag.*, May, 1906, etc.).

The evidence on which this conclusion is based is as follows:—

(1) At Boghead (1 mile E. of Dinnet Station), at Heughhead near Aboyne, and elsewhere farther down the valley of the Dee the only boulder-clay exposed is a hard "till". [At Aberdeen three boulder-clays can be distinguished, but these belong to earlier stages of the Ice Age.] At two points between Dinnet House and Cambus o' May Station a loose sandy boulder-clay (with striated stones) is exposed in the bluffs on the north bank of the river. It is covered by 6-8 feet of water-worn gravel and boulders. A similar boulder-clay is seen in gravel pits by the side of the main road between Dinnet and Cambus o' May Stations. At no point, unfortunately, can the test of superposition be applied to determine the relative age of the two boulder-clays; but the difference in character is striking.

(2) The moraines are very fresh in appearance and have suffered less degradation than those found lower down the valley.

The glacier at the time of its greatest eastward extension terminated somewhere near the great bend of the river opposite the farm of Boghead. Here the moraines on the hill-slopes south of the Dee cease abruptly.

At this time the ice surmounted the Cnoc Dubh ridge and fanned out over the Coldstone and Dinnet basins. The portion least impeded by the form of the ground was that which followed approximately the line of the river and terminated as indicated above.

The glacial phenomena of this portion of the Dee Valley are peculiarly interesting, and I propose to deal with them at greater length elsewhere.

The course of the river through the rock-gorge at Dinnet, it may be added, is in all probability the result of glacial diversion. Borings to the north of the existing channel would doubtless reveal the pre-glacial bed of the Dee.

The terminal moraines of the glaciers of the Fourth Glacial Stage can also be traced in the valley of the Feugh.

*Note (April, 1913).—*In *Mem. Geol. Seconey, Suppl. of Sheet 65 p.p. 123, 124 (1912)* it is said that Dr. Jamieson (*Q. J. G. S.*, 1874 p. 324) stated that the "great valley glacier" of the Dee formed the moraines, *frances* to about Cambus o' May + Dinnet. What Dr. Jamieson really meant as is evident from the context (although he used the term "valley glacier") was that the ice in its retreat towards the mountains from the sea made a prolonged pause there. What I mean above is that the Valley Glacier, using the term in the technical restricted sense in which it is applied in Scottish glacial geology, advanced to Dinnet + no further, & that the glacial phenomena of the Dee Valley above & below this point are different. This is quite a different statement from Dr. Jamieson's and admits of definite proof. No proof is given in the memoir cited above.

Further "the great sheet of gravel which covers the moor of Dinnet below Cambus o' May" (*ibid.* p. 124) is certainly to be attributed to "waters issuing from the glacier of the Dee Valley"; but it obviously is not a simple overwash apron (*supp.* 55-57; 51, 52). To explain in detail the manner of its formation would have required more space than could be given to it here, and raises many interesting problems. Hope to deal with these soon.

BIBLIOGRAPHY.

For the convenience of readers there is here given a list of publications dealing with the topics discussed in the foregoing pages.

The Roman numerals refer to the sections of this work : the asterisks indicate publications that deal specifically with the Dee Valley or adjacent districts.

- I. * Geological Survey Maps (one-inch). Sheets 65, 66, 67, 75 (with memoir), 76 (with memoir), 77.
 - * *Summary of Progress of Geological Survey*, 1897-1902.
 - * *The Geology of Lower Strathspey*. (Explanation of sheet 85 of 1-inch map.)
 - * *The Scenery of Scotland*, by Sir A. Geikie.
 - The Geology and Scenery of the Grampians*, by P. Macnair.
 - The Scenery of Switzerland*, by Lord Avebury.
 - Scientific Study of Scenery*, by J. E. Marr.
 - Geological Magazine* (1883). "The Secret of the Highlands," by Prof. Lapworth.
 - Quarterly Journal of the Geological Society*, vol. lx.
- II. * *Scottish Geographical Magazine*, 1901.
 - River Development* (Progressive Science Series), by Prof. I. C. Russell.
 - Physical Geography*, by Prof. W. M. Davis.
- III. *Physical Geology and Geography of Ireland*, by Prof. Hull.
 - Natural Science*, 1899. "On the Development of Rivers," by Mr. Buckman.
 - Geographical Journal*, 1895. "On the Development of Certain English Rivers," by Prof. W. M. Davis.
 - Quarterly Journal of the Geological Society*, 1902. "Origin of the River System of South Wales," by A. Strahan.
- IV. Works by W. M. Davis, J. E. Marr, and Lord Avebury mentioned above.
- V. * Papers by Dr. T. F. Jamieson in *Quarterly Journal of Geological Society* for 1858, 1860, 1865, 1874, 1882, and in *British Association Report*, 1859.
 - The Great Ice Age*, by Prof. James Geikie.
 - Prehistoric Europe*, by Prof. James Geikie.
 - Fragments of Earth Lore*, by Prof. James Geikie.
 - Man and the Ice Age*, by G. F. Wright.
 - Ice-work Past and Present*, by Prof. T. G. Bonney.

Glacial Geology of England and Wales, by H. C. Lewis.
Summary of Progress of Geological Survey, 1901, pp. 186-7 (Origin of Eskers),
Geological Magazine, 1897. "The Pleistocene Ice-sheet of N. America," by
 W. O. Crosby.

Geological Magazine, 1894-5. "Physiographical Studies in Lakeland," by
 J. E. Marr.

Quarterly Journal of Geological Society, 1898. "Glacial Geology of Spitz-
 bergen" (Englacial Streams), by Gregory and Garwood.

Quarterly Journal of Geological Society, 1902. "Glacier Lakes in the Cleve-
 land Hills," by Prof. Kendal.

* *Bathymetrical Survey of Scottish Freshwater Lochs*. (Loch Muick.)

* *Proceedings of the Royal Physical Society of Edinburgh*, 1906.

VI. *The Scenery of Switzerland*.

Quarterly Journal of Geological Society, vol. xxix. "Alluvial Deposits of
 the Upper Indus Basin," by Mr. Drew.

VII. *Proceedings of the Royal Physical Society of Edinburgh*, vol. vii., 1883.

"Summary of Opinions on the Origin of Valley Terraces chiefly known
 as River Terraces," by Hugh Miller.

Quarterly Journal of Geological Society, 1874.

VIII. *The Scenery of Scotland*.

Rocks, Rock-weathering and Soils, by G. P. Merrill.

INDEX OF LOCALITIES.

- ABERARDER, 26.
 Aberdeen, 7.
 Aboyne, 10, 33, 45, 65, 71.
 Affrusk, Craig of, 49.
 Allt an Gleann Mor, 16, 17.
 Allt an Ruidh Ghil, 17, 18.
 Alltanodhar Shieling (Glen Ey), 28.
 Angel's Peak, 10, 78.
 An Lochain, 16.
 Aucherrie (Glen Ey), 27.
 Auchlossan, Loch of, 30, 34, 35.
 " Farm, 35.
 Aven, River, 30, 39, 41.

 BALLATER, 23, 51, 52, 56, 60.
 Balmoral, 6, 44.
 Balnagowan Hill, 30, 36.
 " Farm, 36.
 Balnoe, 26.
 Banchory, 10, 36, 73.
 Bandory, 65.
 Battock, Mt., 75.
 Bean's Hill, 58.
 Beinn a Bhuird, 19, 60, 70.
 Beinn a Glo (Ben-y-Glo), 13, 16, 21, 81.
 Beltie Burn, 22, 30, 60.
 " , Hill of, 30.
 Bielside, 38, 59.
 Birkhall, 43.
 Blackness (Strachan), 39, 49.
 Blairydrine, 48, 49.
 Bogendreep, Bridge of, 40.
 Boghead (Dinnet), 84.
 Bogingore, 52, 54.
 Bogloch (Lumphanan), 35.
 Bog More (Tarland), 35.
 Borrowstoun, 59.
 Brackley, 42.
 Braemar, 10, 19, 25, 26, 70.
 Braeriach, 8, 10.

 Bratheus, 30.
 Brimmond Hill, 59.
 Broadwater, 31.
 Broomhill, 37.
 Buidhe, Loch, 67.
 Builg, Loch, 20, 44.
 Burn o' Vat, 52, 55, 56, 76.
 Bynac Burn, Map 3.
 " Shieling, 17.

 CAIRNBALLOCH Wood, 47.
 Cairncry Quarries, 23.
 Cairngorms, 16, 20, 44, 75, 77.
 Cairntoul, 10, 78.
 Cairnwell, 81.
 Calladrum, 48.
 Cambus o' May, 22, 42, 45, 52, 57, 79.
 Canny, Burn of, 22, 30.
 Carn a Mhaim, 77.
 " Clamhain, 16.
 " More, 19.
 Castlehill (Strachan), 71.
 Clais Fhearna (Fhearnaig), 17, 19, 64, 65.
 Clenter, Mill of, 41, 42, 45.
 Clochnaben, 66.
 Clunie, River, 19, 70, 81.
 Cnoc Dubh, 22, 34, 42, 51, 52, 56.
 Coldstone, Logie, 37, 84.
 Colonel's Bed (Glen Ey), 26.
 Conachcraig, 21, 44.
 " , Little, Fig. 1.
 Corbie Loch, 38.
 Corrach, The (Mt. Keen), 76.
 Corriemulzie Burn, 73.
 Coull, Hill of, 23.
 " , Bridge of, 35.
 Craigendarroch, 22, 60.
 Craiglug (Aberdeen), 74.
 Craig na Dala Beg, 20.
 " " Mor, 20.

- Craignarb, 30, 65.
 Crannoch Hill, 28.
 Crathes, 71.
 Crathes, Leys of, 37.
 Creaganriach, 28.
 Crofthead, 50.
 Culblean, 28, 42, 51, 52.
 Culsten Burn, 29 (note).
 Culter, 33, 58, 60, 71.
 „ , Bridge of, 33.
 Cummie, Mill of, 39.

 DAVAN Loch, 32.
 Dearg, Ben, 21.
 Dee, Glen, 8, 13, 14, 25, 77.
 „ , Linn of, 73.
 „ , Wells of, 8.
 Deecastle, 42.
 Denmill (Culter), 31.
 Derry, River, 44.
 „ , Glen, 64.
 Dess, Burn of, 34.
 „ , Muir of, 34.
 „ , Bridge of, 34, 65.
 „ , Slog of, 35, 36.
 Desswood House, 35.
 Devil's Bite (Clochnaben), 66, 77.
 „ Point, 10, 77.
 Dinnet, 3, 10, 22, 33, 42, 45, 51, 71, 84.
 Don, River, 10, 77.
 Drum Castle, 46.
 Drumhead F.C., 41.
 Dry Den, 59.
 Dubh Loch, 24, 67.
 „ Glen, 63, 64.
 Durriss House, 48.
 Dye, River, 30, 39, 40, 41, 66.

 Eddart, River, 12, 13, 19.
 Elrick Hill, 59.
 Etchachan, Loch, 24.
 „ , Corrie, 76.
 Eunach, Loch, 21.
 Ey Burn, 19, 27, 28, 81.
 Ey, Glen, 27, 28.

 FARE, Hill of, 46.
 Feardar Burn, 26.
 Felagie, 26.
 Feshie, River, 12, 19, 25,
 Feshie-Geldie, 12, 13.
 Feugh, River, 30, 39, 40, 41, 42, 47, 69,
 71, 73.
 Feughside Inn (= Whitestone), 46.
 Fiddich, River, 7.
 Fountainhall Road (Aberdeen), 7,

 GAIRN, Glen, 20.
 „ River, 20, 44, 69.
 Gairnshiel, 69.
 Garlogie, 31.
 Garchory, 8, 13, 25.
 Garrol Hill, 47.
 „ Burn, 47, 48, 49, 50.
 Geallaig Hill, Fig. 1.
 Gelder, Glen, 66.
 Geldie Burn, 12, 14, 16, 19.
 Gellan, 39, 49.
 Geusachan, Glen, 25.
 Girdleness, 20.
 Girnock, Glen, 21, 66.
 Glas Allt (L. Muick), 69.
 Glassel, 64.
 Glenfinzie, 66.
 Glenhead (Durriss), 49.
 Glenmillan House, 60.
 Glenmuick House, 43.
 Gormack Burn, 46.
 Great Glen (Glenmore), 1.

 INSCHBOBART, 44.
 Invercauld Bridge, 26, 73.
 Iutharn, Ben, 81.

 KEEN, Mount, 76.
 Kemnay, 45.
 Kerloch, 75.
 Kincardine O' Neil, 10, 73.
 Kinnord, Loch, 51, 54, 55, 57.

 LEARNEY (North Lodge to House of), 66.
 Leuchar Burn, 31, 33, 58.
 „ Moss, 31.
 Loch, Loch, 16.
 Lochan a Bhata (= Poll Bhat).
 Lochan-nan-Cnapan, 21.
 Lochan Uaine, 24.
 Lochnagar (Mt.), 6, 20, 21, 44, 76.
 „ (Loch), 24.
 Logie Coldstone, 37, 84.

Loirston, Loch of, 32, 38.
Lui, River, 44.
,, , Glen, 64.
Lumphanan, 22, 35, 60, 64.

MARYFIELD Hill, 50.
Meall Gorm, 44.
Mortlich Hill, 34.
Morven, 21, 22, 28, 29, 80.
Moss-side (Strachan), 42, 49.
Muick, Coyles of, 80.
,, , Glen, 44.
,, , Linn of, 73.
,, , Loch, 24, 25, 43.
,, , River, 67.
Muickdhu, Ben, 64.
Mulloch Hill, 48.
Murtle, 31, 38, 45, 46, 58, 59.

NEWMILL Hill (Culter), 33, 60.
Nigg, Bay of, 33, 74, 75.
Nith, 7.
Normandyke Hill, 60.

PANANICH, 42.
Park, 36, 48, 75.
,, , Loch of, 38, 39.
Pitfodels, Hillhead of, 59.
Poll Bhat, 63.
Potarch, 39, 65, 73, 80.

QUARTONS Moss, 46.
Queen's Hill, 30.
Quoich, River, 19, 60, 70, 73.
,, , Glen, 20, 61, 62, 64.

RAEMOIR, 46, 64.
Rashy Burn, 29.

Rotten of Gairn, 58.
Rotten, Moss of, 31.

SATAN's Den, 65.
Schiehallion, 3.
Shade, Mount, 66.
Sheecho Burn, 47, 48, 49.
Shillofad, 47.
Silver Burn, 31, 58.
Skene, 32, 58.
,, , Loch of, 31, 32.
Slugain, Glen and Burn, 19, 60, 61.
Sockaught (= Pressendye), 37.
Spey, 10, 12, 21, Appendix 1.
Strachan, 30, 39, 41, 71.
Stranduff, 22, 80.

TARFF, River, 16, 19.
Tarland, 37, 52.
,, , Burn, 22, 30, 36.
,, , Loch, 30.
Temple Burn, 60.
Tillylodge, Slack of, 66.
Tilquhillie, Burn of, 50.
Tilt, Glen, 13, 16, 17, 19, 21, 25.
,, , Loch, 17.
Tomnakiest, 52.
Torphins, 22, 31, 65.
Tullich, 42.
,, Burn, 29, 35, 70.
Tullos Hill, 38.

UARN (Iutharn), Ben, 81.

WARDEND (Durriss), 47, 48.
Whitestone (Feughside Inn), 39, 46, 71.
Wisdomhow, 57.
Woodend School (Durriss), 57.